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AFAL-TR-74-131

DIGITAL SIGNAL TRANSFER UNIT MULTISENSOR DISPLAY SYSTEM

TEXAS INSTRUMENTS, INC.
EQUIPMENT GROUP

December 1975

TECHNICAL REPORT AFAL-TR-74-131

FINAL REPORT FOR PERIOD 1 FEBRUARY 1973 - 15 DECEMBER 1973

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AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

This technical report has been reviewed and is approved for publication.

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This report describes the development and testing of a Digital Signal Transfer Unit Multisensor Display System (DSTUMDS) for the F-4E aircraft. The objective of the program was to develop a new avionics display system that offers non-degraded performance, an improved operator-system interface, growth capability, and improved reliability. In addition, the equipment was designed and developed as a direct replacement for the analog Multisensor Display Group (MSDG) presently found in production F-4E aircraft, with no

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20. ABSTRACT (Cont)

requirement for aircraft modifications or wiring changes.

The DSTUMDS provides non-degraded display presentations of both low refresh rate radar data and high refresh rate electro-optical sensor information on the same display monitor. The electro-optical sensor information is displayed directly on the short persistence phosphor cathode ray tube without being processed. Digital processing techniques and random access memory technology are used to convert the radar data input rate to a suitable display output rate.

A nineteen-flight evaluation of the DSTUMDS equipment was conducted by the Air Force Flight Test Center at Edwards AFB between 9 May and 6 June 1973. Following that evaluation, several modifications and adjustments of the equipment were performed and the system was subjected to an IOT&E by the Tactical Fighter Weapons Center at Nellis AFB. The successful completion of the DSTUMDS development and testing program has led to a recommendation by Tactical Air Command that a digital signal transfer unit be procured to replace the MSDG in production F-4E aircraft.

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SECTION I

INTRODUCTION

This document is a final report which describes the design, development and evaluation of a Digital Signal Transfer Unit Multisensor Display System (DSTUMDS) for the F4-E aircraft and associated avionics. The DSTUMDS concept is based on the utilization of digital techniques and offers a new approach to extend the capabilities of display technology to meet the increasing demands of modern avionics systems.

The DSTUMDS program was performed under contract F33615-73-C-1212 for the AFSC/Air Force Avionics Laboratory (AFAL) Wright Patterson AFB, Ohio.

The DSTUMDS program can be considered as consisting of four basic phases: development, bench integration, flight evaluation at Edwards AFB, California, and flight evaluation at Nellis AFB, Nevada. The development phase consisted of the design and fabrication of one flyable display unit and safety of flight certification of that equipment. The fabricated unit was bench integrated with F4-E avionics at MacDonnell Douglas, St. Louis, Missouri, to ensure equipment compatibility with the F4-E sensor and weapons systems. The initial flight test at Edwards AFB was designed to test the feasibility of the DSTUMDS concept. During this flight test nineteen flights were conducted. The flight test at Nellis AFB consisted of both comparison of the DSTUMDS performance related to the F4-E Multisensor Display Group (MSDG) display system and AFAL tests conducted to evaluate specific DSTUMDS parameters. During the Nellis test program forty-three flights were completed.

A large portion of the flight evaluation data, specifically from the Nellis AFB tests, is not available to Texas Instruments. However, the results of the development and Edwards AFB test phases show that the DSTUMDS has demonstrated satisfactory capability and promises to provide high performance, long life display capability for the F4-E aircraft.

The body of this report outlines the program objectives, the general theory of operation and describes the tests performed. The problems encountered and solutions implemented are discussed in detail. General conclusions are listed and recommendations arising from the test program are offered.

SECTION II

PROGRAM OBJECTIVE (U)

The increased use of multiple sensors in modern avionics systems is limited by conventional display technology. The use of analog display techniques to meet all aircraft system requirements has resulted in design trade-offs which impose restrictions on performance, reliability and the man/machine interface. A new display approach is needed which can meet all aspects of multisensor application. The Digital Signal Transfer Unit Multisensor Display System (DSTUMDS) concept, which is based on the rapidly expanding computer industry, is a new display technique which offers long-life equipment with non-degraded performance and optimum human operator interface.

The objective of the DSTUMDS program is the development of a flyable multisensor display using digital processor techniques. Another objective is the testing and evaluation of the equipment capability to meet the requirements of the F4-E avionics multisensor configuration.

The program tasks outlined by AFAL Statement of Work are design and fabrication of one display system, equipment safety of flight certification, and flight test in F4-E aircraft.

SECTION III

EQUIPMENT DESCRIPTION

A. Equipment Configuration and Interface

The Digital Signal Transfer Unit Multisensor Display System (DSTUMDS) consists of three (3) line replaceable units (LRU's).

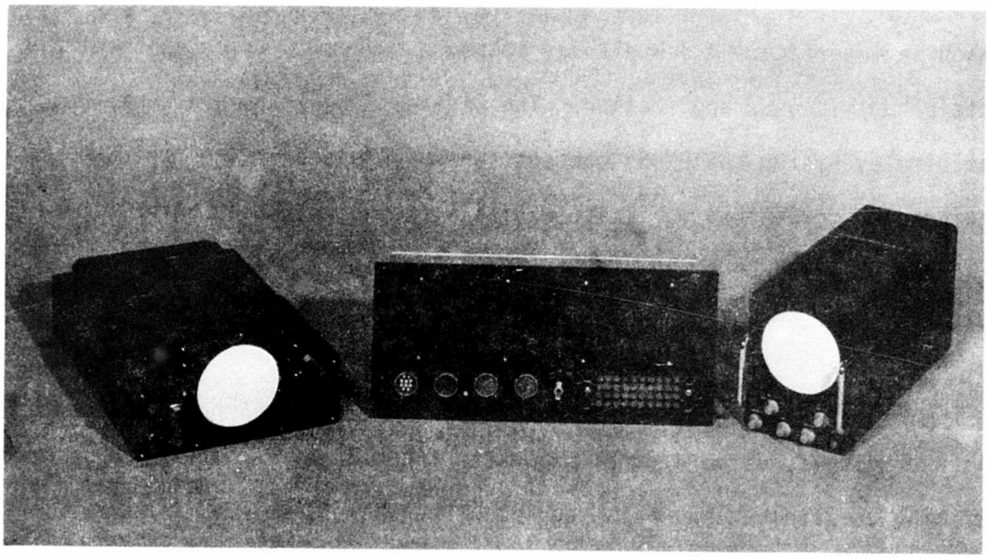

Figure 1. DSTUMDS Line Replaceable Units

Figure 1 presents these three (3) LRU's which are, from left to right: the Pilot's Indicator (PI), the Air Indicator Control Unit (AICU), and the Radar Pilot's Indicator (RPI). The DSTUMDS is designed to replace the F4E Multisensor Display Group (MSDG) as a three-box system replacement with no requirement for electrical or mechanical aircraft modifications.

The DSTUMDS interfaces with the following sensors and F4-E weapons system components:

AN/APQ-120 Radar System

AN/ASG-26 Lead Computing Optical Sight

AN/ASQ-91 Weapons Release Computer

AGM-65A Guided Missile

MK-1 MOD 0 Guided Weapon

Paveway Weapons (with standard 525 line television format)

AN/ASK-1 TISEO - Target Identification System, Electro-optical

B. DSTUMDS Theory of Operation

1. Functional Organization

Primary weapons system interface is performed by the AICU LRU. This unit processes low refresh radar data and weapons delivery computer symbology into a high refresh format and provides either TV rate radar or TV guided weapon data to the indicator as analog video and horizontal and vertical sync gates. The cathode ray tube (CRT) indicator LRU's accept the AICU LRU outputs and provide sweep generation and video processing to yield a video raster presentation for television or a raster presentation with multiplexed calligraphic symbology for radar sensors. Figure 2 outlines the DSTUMDS LRU interface.

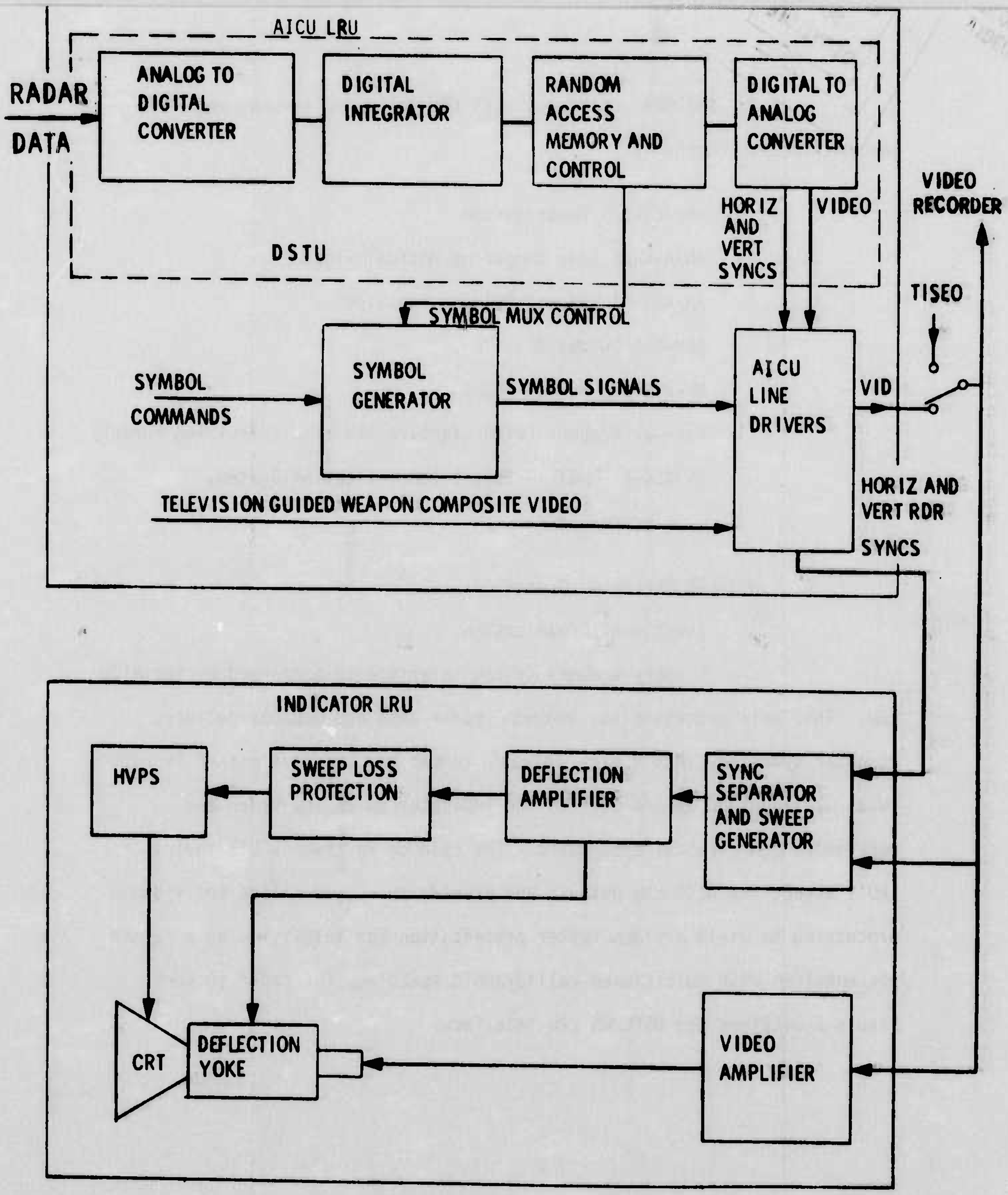

Figure 2. DSTUMDS Signal Flow Block Diagram

Figure 2 depicts the DSTUMDS interface with the TISEO sensor and video tape recorder. Either TV or radar video is routed to each indicator via existing aircraft cabling. Signal switching is provided in the aircraft weapons system to select either AICU or TISEO video. This same data line is interfaced with the video tape recorder. It should be noted that the DSTUMDS symbol data is multiplexed into the horizontal and vertical radar syncs and cannot be recorded by the external video tape mechanization.

2. AICU Functional Description

The AICU LRU contains the DSTU, symbol generator, television guided weapon (TVGW) interface and internal low voltage power supplies required for LRU operation.

a. DSTU

The Digital Signal Transfer Unit converts low refresh radar data into a television rate format in four basic functions: analog-to-digital (A/D) conversion, digital integration, storage in a metal oxide semiconductor (MOS) random access memory RAM and digital-to-analog (D/A) conversion. Because of the inherent accuracy of the digital technique, data rate conversion is accomplished with minimum target positional and analog amplitude errors.

(1) Analog to Digital Converter

The radar analog data, antenna scan video amplitude and range logic are converted to binary codes by the A/D converter. The video amplitude is converted into a three-bit digital word (eight levels) by the video quantizer. The radar antenna position is translated into a digital word describing 160 position azimuth bins over the 120 degree antenna

scan coverage. Each radar range is digitally coded into 512 range segments (range cells) by clocking the active radar video sweep at a clock rate counted down from a crystal controlled master clock which has been synchronized with the radar transmitter pulse. The range and azimuth codes are utilized to determine the random access memory addresses at which the target video code is stored.

(2) Digital Integrator

The binary coded video amplitude data is digitally integrated over several radar transmitter pulse repetition periods (PRP) to derive the average target amplitude and improve the signal to noise ratio. Effectively, video data is integrated across one azimuth bin (1/160th of the total 120 degree antenna coverage) by adding each new PRP to its azimuth beam amplitude history. The history (old data) is reduced by a Beta factor, prior to addition, to create an integration response tailored to the radar PRP and antenna scan rate parameters.

(3) Random Access memory

The random access memory organization can be visualized as a three dimensional matrix as shown in Figure 3. The Y-axis is made up of range cells and the X-axis is composed of azimuth cells, the Z-axis contains the video amplitude code. In the matrix, each target has eight three-bit possible amplitudes which may be stored in 512 possible range locations and 160 possible azimuth locations. Matrix, or memory, capacity is 3 x 512 x 160 = 245, 760 bits.

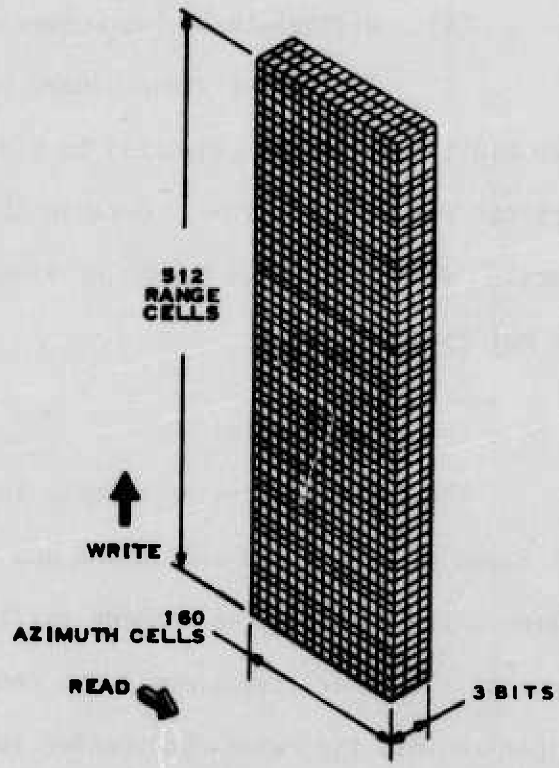

Figure 3. DSTUMDS Memory Matrix

Integrated data is read into the memory matrix in the range direction one azimuth bin at a time. As the radar antenna moves from left to right, the memory matrix is updated with the azimuth scan information.

Memory read cycles, controlled by memory timing, consist of reading all azimuth bins at a constant range address. In this manner, one horizontal line of video is produced. Successive memory interrogation produces a read data frame composed of 512 such horizontal **video** sweeps. To provide a flicker free display, the read frame is divided into two fixed 2:1 interlaced fields composed of 256 lines each. The average read field rate is 63.2 Hz.

(4) Digital-to-Analog Converter

The target video binary code and its memory X and Y addresses are digital-to-analog converted to yield analog video and horizontal and vertical raster sync gates. Because the sync gates are derived from the video function address, a high degree of video-to-raster registrational accuracy is maintained.

b. Symbol Generation

The symbol generator accepts logic and symbol position data from the F4-E avionics system and provides X and Y deflection voltages to produce calligraphic symbology in the cathode ray tube indicator. In order to provide simultaneous stroke written symbols and radar video, the symbol data must be multiplexed into the radar read raster vertical dead time; symbol generation and multiplexing are controlled by the random access memory timing and control circuitry. Straight line symbols (vertical and horizontal lines) are generated by vertical and horizontal sweep integration, controlled by multiplex gates. Symbols requiring sine and cosine modulation, such as circles, are generated in these same integrators which are switch mechanized as a linear differential analyzer. The outputs of the symbol generator are horizontal and vertical sweeps and symbol video or intensity gates. The horizontal and vertical sweeps are combined into the radar horizontal and vertical sweep data. The video gates are combined into the radar video.

c. Line Driver

The line driver function serves three purposes: TVGW interface, symbol/radar raster summation, and TVGW/radar mode video selection

for each indicator. The line driver provides switch selection for each TVGW station and signal buffering between the missile and each indicator. The radar sync and symbol deflections are combined in the line driver as are the radar video and symbol intensity gates. In order to be able to record either TV or radar raster video, the horizontal and vertical radar sync signals are also combined with the video to yield composite video. Logic signals into the line driver assembly select either radar or TVGW video for each indicator.

3. Indicator LRU Functional Description

The indicator LRU's, although of different form factor, are electrically identical. The units accept either TV or radar data. They also provide a non-fade video raster display presentation on a high brightness short persistance phosphor cathode ray tube.

a. Sweep Generator/Synchronization Separator

The synch separator function removes video from the composite video and separates the horizontal and vertical synchs into horizontal and vertical sweep gates. These gates subsequently undergo linear integration in the sweep generator to produce horizontal and vertical sweep waveforms. In the particular instance of the radar Plan Positive Indicator display (PPI) mode, the sweep generator linear integrators are logic mechanized into a linear differential analyzer which generates a sine cosine modulated spiral scan raster. The synch separator also contains the logic circuitry required to remove the multiplexed symbol signals from the radar synchs. These signals are passed directly to the deflection amplifier.

b. Video Amplifier

The video amplifier converts the sensor video signals to voltage levels compatible with cathode ray tube operation. The video amplifiers also contain video gamma correction.

c. Deflection Amplifiers

The deflection amplifiers convert the deflection voltage into current signals for the CRT deflection yoke. Sweep waveforms from the deflection amplifiers are also utilized to control the power input to the CRT high voltage power supplies. This prevents cathode ray tube phosphor burn in the event of a deflection signal loss.

C. Detailed Theory of Operation

Detailed circuit theory is not included in this report. Such data is outlined in detail in Texas Instruments Proposal Number EG 73-007, dated 10 January 1973.

D. Mechanical Description

1. Air Indicator Control Unit (AICU)

The DSTU AICU weighs 37 pounds. It is mechanically interchangeable with existing MSDG AICU. The unit is 20" wide, 9 1/8" high, and 8" deep. An outline drawing is presented in Figure 4.

The unit is constructed of 6061 aluminum alloy and the design is directed toward the use of aluminum casting. Rapid access to 29 printed circuit board positions is provided by the use of MS 21332, snap slide fastners.

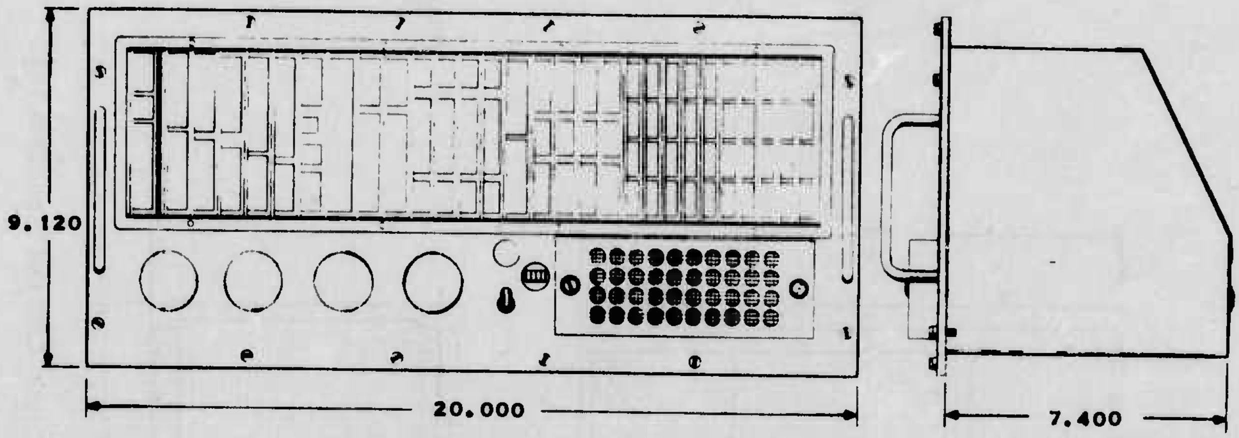

Figure 4. Air Indicator Control Unit Outline Drawing

Cooling is accomplished with two 55 CFM fans, working against a pressure differential of .25 inches of water. The inlet to outlet temperature rise is less than 8 C. Cooling air is filtered through a ten (10) Pore-per-inch, flexible polyester foam material to effectively maintain a clean interior.

2. Pilot's Indicator (PI)

Dimensions are controlled to provide a compatible fit with the AN/ASG-26 lead computer sight. The pilots indicator weighs 32 pounds. An outline drawing is presented in Figure 5.

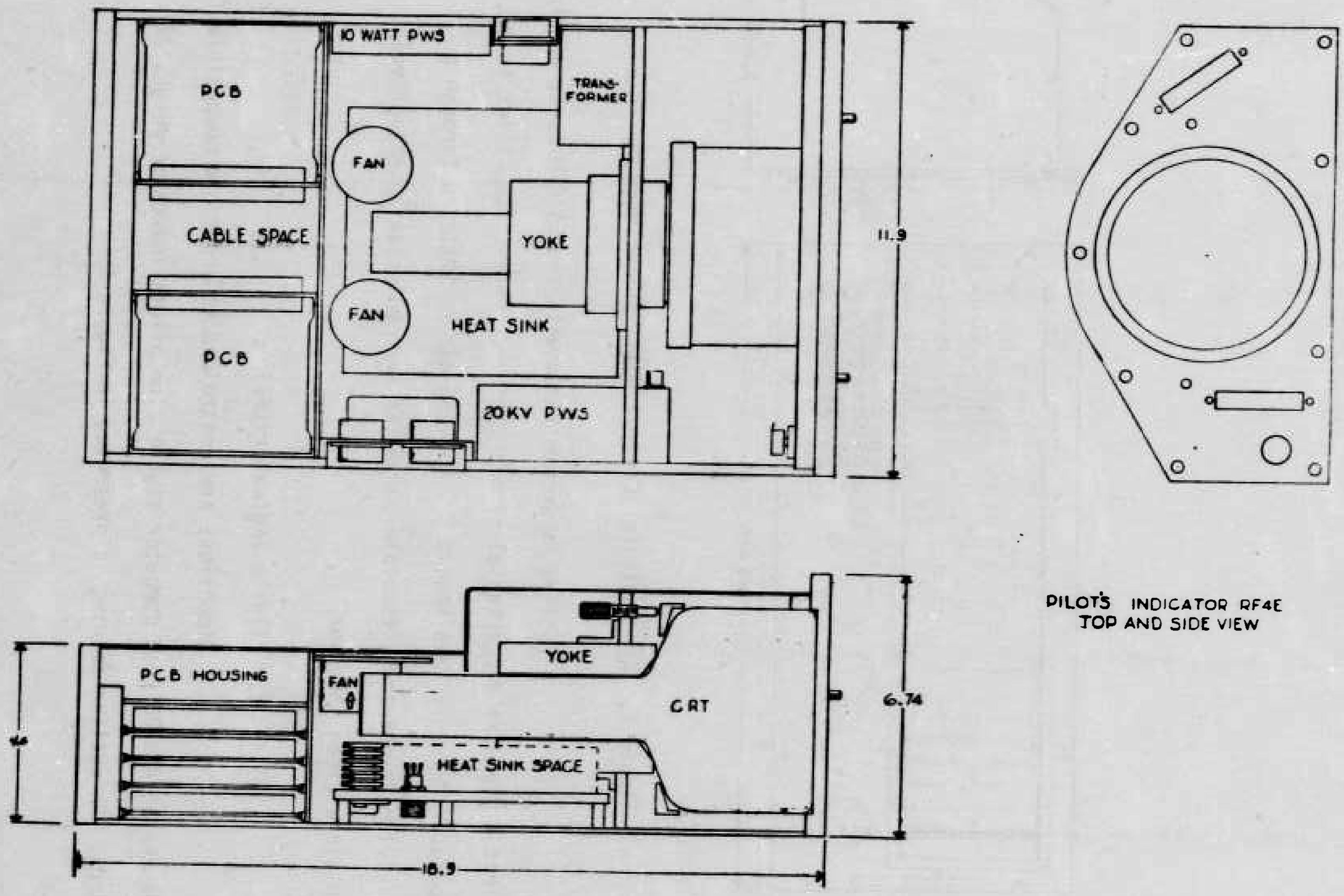

Figure 5. DSTUMDS Pilot's Indicator LRU Outline Drawing

This unit is also constructed of 6061 aluminum alloy. The design is rigid to prevent transmission of vibration to the ASG-26 gun sight.

Two 32 CFM fans, operating against a differential of 0.1 inch of water provide the cooling. Ambient air enters the ports at various locations on the box. It passes over heat emitting devices and is expelled through the top center of the box. Power supply heat sink assemblies are mounted to individual cooling surfaces (modules) for high rate, heat dissipating devices.

3. Radar Pilot's Indicator

This unit is electrically identical to the pilot's indicator, previously described. Outline dimensions are shown in Figure 6. Unit weight is 27 pounds.

This unit is also constructed of 6061 aluminum alloy. Printed circuit boards are interchangeable with those used on the pilot's indicator. The power supply (heat sink chassis) is not mechanically interchangeable with its counterpart in the pilot's indicator, however, it is electrically compatible.

Cooling is accomplished with two 32 CFM fans, operating with a 0.1" water differential. Cabin air is drawn through sized ports in the units outer wall and expelled through the top center.

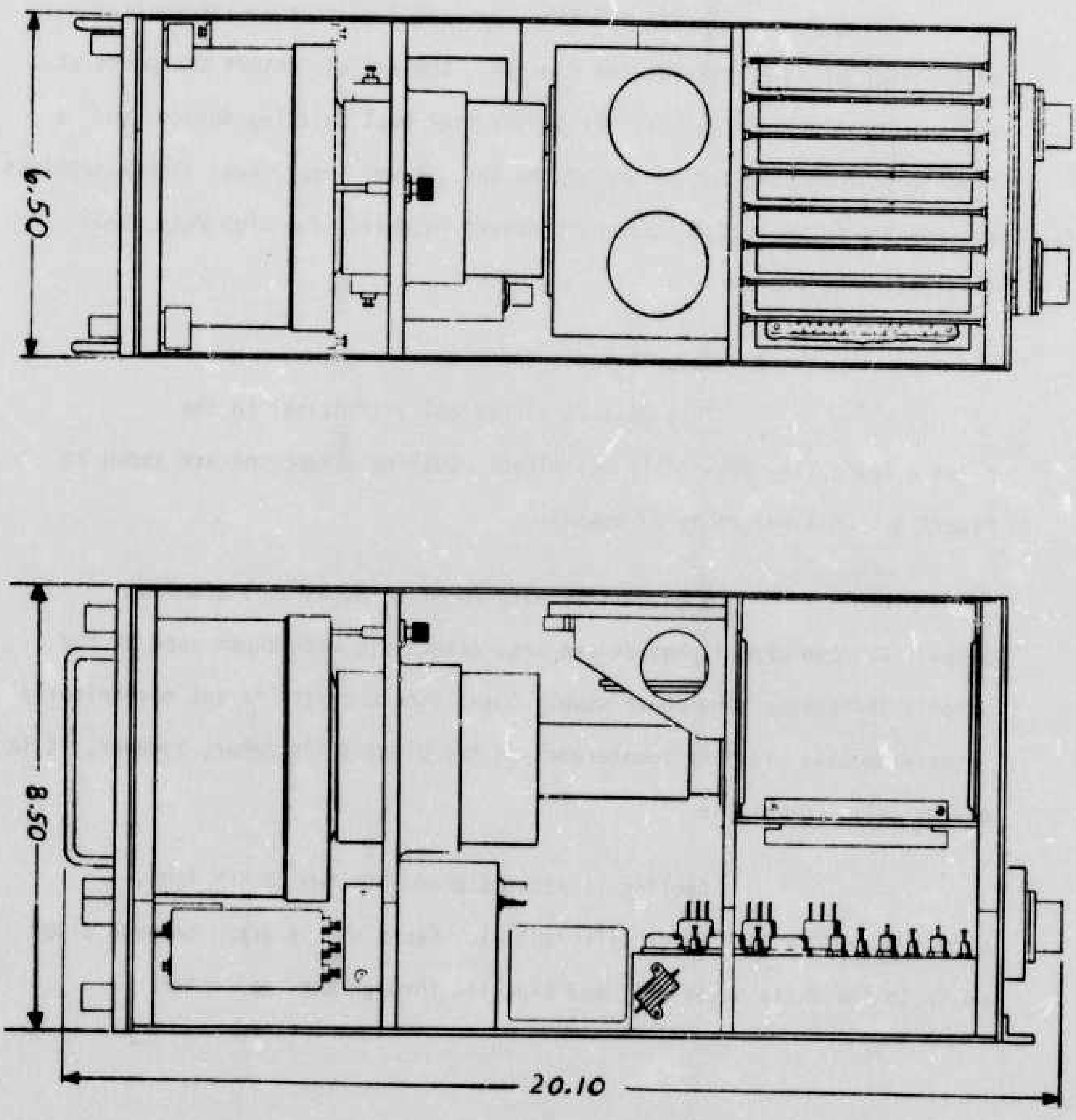

Figure 6. Radar Pilot's Indicator Outline Drawing

E. Display Formats

The DSTUMDS provides four basic modes of operation:

B-scan format
B-scan acquisition and track format
PPI spiral scan radar
The standard 525 line electro-optical formats

Pictorial descriptions of each display is shown in Figure 7.

The B-scan search format is a 512-line, 63.2 Hz, 2:1 interlaced raster presentation with a 1:1 aspect ratio. Radar video is presented as a 118-degree nominal search display. Radar symbology is displayed during raster vertical sweep dead time.

The B-scan acquisition and track format is identical to the B-scan format in angular width. Radar data is read directly from the DSTU digital integrator and displayed as video superimposed on a series of radar range sweeps. The radar information is time shared with calligraphic symbology.

The PPI spiral scan format is displayed as a depressed-center raster containing 512 range arcs in a 63.2 Hz, fixed 2:1 interlaced field. In PPI wide scan, the video is presented with a nominal angular width of 118 degrees. In PPI narrow scan, video is presented in a 45-degree sector scan. All radar mode symbology consists of calligraphic characters written during the raster vertical retrace time.

The electro-optical display presentation is conventional x-y TV format provided as a 525-line, 60 Hz, 1:1 aspect ratio raster.

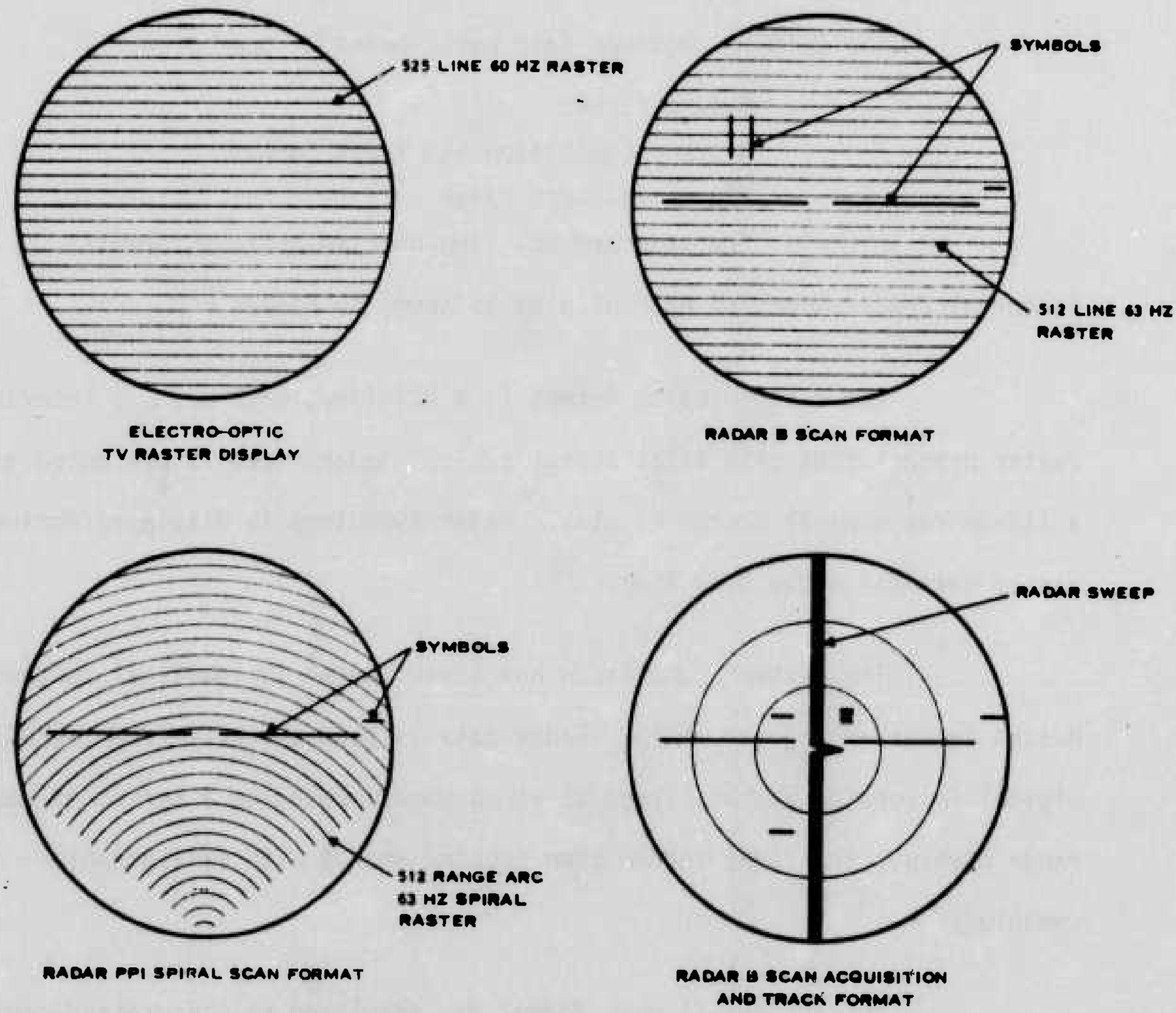

Figure 7. Multimode Display Formats

F. DSTUMDS Performance Parameters

1. DSTU Parameters

Memory type - Metal Oxide Semiconductor (MOS)

Random Access Memory (RAM)

Radar Mode Resolution - 512 range cells per display diameter.

160 azimuth bins per 120-degree scan

Dynamic Range - Eight $\sqrt{2}$ gray shades.

2. Cathode Ray Tube Parameters

Bandwidth - 10.5 MHz

CRT Spot Size - .005 ± .001 inches

Light Output - 1000 ft Lamberts minimum

Dynamic Range - 100:1 in dark environment

32:1 in lighted room

G. DSTUMDS Special Features

Four special features are designed into the DSTUMDS for test and evaluation of their effect on overall system performance and the man machine interface. These features are:

Peak detection
Threshold detection
Digital filtering
Display freeze

Peak detection is mechanized into the DSTU video quantizer. The technique consists of detecting the highest amplitude signal, which occurs within a quantizer clock sample gate, and selection of this peak signal for

subsequent integration. The net effects are: increased detection capability of the DSTU and reduced display collapsing loss which may be incurred.

Threshold detection consists of the selection of a signal occurring above a selected level and the display of this signal as the maximum brilliance possible on the CRT. The threshold level, selected for threshold detection, encompasses all signals above the first three gray shades; such signals are displayed as gray shade eight.

Digital filtering is an interpolation method which is designed to provide a display smoothing effect. Target gray shades and azimuth resolution are multiplied by a factor of four to increase the number of digital steps existing between adjacent targets on their leading and trailing edges.

DSTU freeze is simply mechanized by inhibiting the memory write function. Memory read continues and the last radar frame (one antenna scan) update remains the memory.

All of the special features are selectable by four manual switches located on the AICU front panel. In the OFF mode, the special features have no effect on system operation.

SECTION IV

DESIGN CONSIDERATIONS

A. Digital Signal Transfer Unit

Principal considerations with respect to the design of the DSTU are:

- Radar resolution and dynamic range
- Form factor constraints
- Operating temperature range
- Read and write timing

All these entities relate directly to memory and storage capacity.

1. Memory Storage

Three basic types of memory storage are available for DSTU design:

- Rotating drum or disc memories
- Shift register memories
- Random access memories

The rotating component devices are excluded by the F-4E aircraft form factor and high G maneuver envelopes. The shift register memory technique was rejected due to the processing speeds required for F-4E avionics application. The availability of such components, with the necessary processing speeds over the required temperature range, appears questionable. The use of a random access memory (RAM) as a DSTU storage element provides a low risk approach. This technique has been successfully used on several digital processors developed by Texas Instruments Incorporated. The ability to store and access data in a non-sequential manner reduces processing speeds and control circuitry.

Two new component technologies are available for the F4-E DTSU RAM mechanization. These are core and metal oxide semiconductor (MOS). Memories of both component types have been extensively tested in Texas Instruments Incorporated equipment. Although a wider temperature range can be achieved with state-of-the-art core memories, the available MOS 1 X 2048 bit (2K MOS) chips, have shown (in environmental testing) that a -54 to +85-degree centigrade operating temperature can be achieved with no performance degradation. The selection of the 2 K MOS chip, as a memory element, is consistent with state-of-the-art digital computer technology. This enables the memory storage element to be packaged into the AICU LRU with minimum thermal and mechanical design risk. Although memory devices of higher density exist, they are either not available in production quantities from multiple sources or they cannot meet the required temperature range.

2. Memory Configuration

The RAM storage element can either be configured as an X-Y matrix with a 1:1 aspect ratio between horizontal and vertical resolution or as a digital rate converter with non-symetrical range and azimuth resolution. In the former case, a radar data conversion from rho-theta to X-Y coordinates is required. In the latter case, the data rate converter accommodates the radar format with no need for any coordinate conversion of the memory addresses.

The minimum display requirements MacDonnell Douglas specification 538700801, is 400 range elements per display diameter and six $\sqrt{2}$ gray shade dynamic range. Selection of the conventional 1:1 aspect ratio requires a memory capacity of 400 x 400 x 3 or 480,000 bits. Consequently, this capacity requires twenty each 4.35 x 4.35 memory storage printed circuit

boards, with an additional three circuit boards, for rho-theta conversion. Investigation of the space available in the AICU LRU showed that, with projected component heat rises above 100 degrees centigrade, very dense packaging is required. A second disadvantage of the 1:1 aspect ratio matrix lies in the rho-theta to X-Y conversion mechanization. The 400 x 400 matrix does not provide sufficient address points, without severe degrading of data positions at mid and long display ranges, to convert a Plan Position Indicator (PPI) display to X-Y. In order to reduce the distortion to a minimum, a matrix of 512 x 512 is required.

The azimuth beamwidth of the AN/APQ-120 radar system exceeds the range resolution by a large margin. In the APQ-120 radar, the number of azimuth cells, required for a radar scan coverage, can be less than the number of range cells per radar range sweep. This can be accomplished without degradation to operational performance. The data rate converter memory-matrix was chosen for the DSTU. The matrix is composed of a number of azimuth bins, proportional to a fractional beamwidth, with each azimuth bin divided into a number of range cells. Each range cell contains the capacity to store a three bit amplitude code for each target. Using this technique, no coordinate transformation takes place, only format rate conversion takes place via the slow write and fast read of the stored data. In the special case of PPI formats, sine and cosine sweep modulation is provided by a linear differential analyzer function contained in each indicator LRU. The result is a TV rate, spiral scan, PPI video raster containing no rho-theta to X-Y coordinate conversion discontinuities.

The DSTU memory matrix is composed of 160 azimuth bins per 120 degree antenna scan. Each azimuth bin contains 512 range elements. Each range element contains a three bit binary amplitude code.

a. Range Resolution

The range resolution requirements for the F-4D configuration is 400 range rings, or elements per display diameter. However, a 512-range-ring configuration was selected to simplify memory partition and periphery timing circuits. The shift registers used in digital integration, temporary read storage, etc., are in binary format (256 bits or 512 bits). Limiting range resolution to 400 range cells would unnecessarily complicate system timing. The additional memory capacity, required for 512 range cells, is more than offset by reduced control circuitry.

b. Dynamic Range

The F-4 dynamic range requirement is a specified six $\sqrt{2}$ gray shades. The digital mechanization can provide dynamic range only in powers of two steps, e.g., two, four, eight, sixteen. The 3-bit dynamic range (eight $\sqrt{2}$ gray shades) is required to meet minimum specification.

c. Azimuth Resolution

Texas Instruments Incorporated's flight test and ground test experience, with the digital rate converter, has shown optimum azimuth resolution to be between one-quarter and one-third beamwidth. Resolutions approaching one half beamwidth have exhibited edge effect and cause degradation of the operator/display interface. The 160 azimuth bin resolution, selected for the DSTU, represents approximately one-fifth of the AN/APQ-120

radar sensor beamwidth. Based on previous experience with similar sensors, this azimuth resolution is considered adequate for target positional accuracy, will exhibit no cosmetic degradation, and at the same time allows a small capacity memory to be utilized.

d. Memory Printed Circuit Board Configuration

The RAM is configured to provide 512 range elements, 3 bits dynamic range and 16 azimuth bins per memory printed circuit board. An additional azimuth resolution of 16 lines per board can be added to the DSTU.

3. Memory Timing

Memory timing is constrained by two entities:

A flicker free data presentation on the read side

The sensor data update rate on the write side

Since the read rate requirement is many times that of the write rate, a non-standard length read/write word is selected. The timing is designed to provide a 12-bit word for write cycles and a 30-bit word for read cycles. The implementation greatly reduces the need for temporary read storage and also reduces read clock frequencies.

4. Video Quantizer

a. Automatic Quantizer Level Adjust

In order to maintain full control of the radar dynamic range in all modes, an automatic level adjust is incorporated into the video A/D converter or video quantizer.

The need for an automatic level adjust can be understood by considering Figures 8 and 9. Figure 8 depicts a situation of low receiver gain. The higher gray shades do not trip or activate the higher gray shade level. The net result is reduced detection, or gray shade response. Figure 9 illustrates the same situation with increased radar receiver gain. Detection is increased, but gray shade response is again lost. In both illustrated cases, the brightness of the display is a direct function of the receiver gain setting.

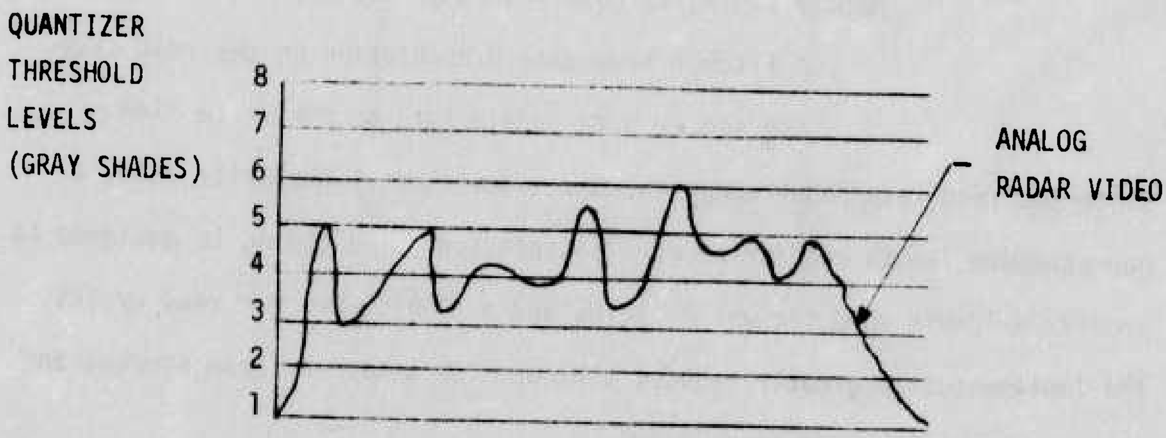

FIGURE 8. FIXED QUANTIZER WITH LOW RADAR VIDEO

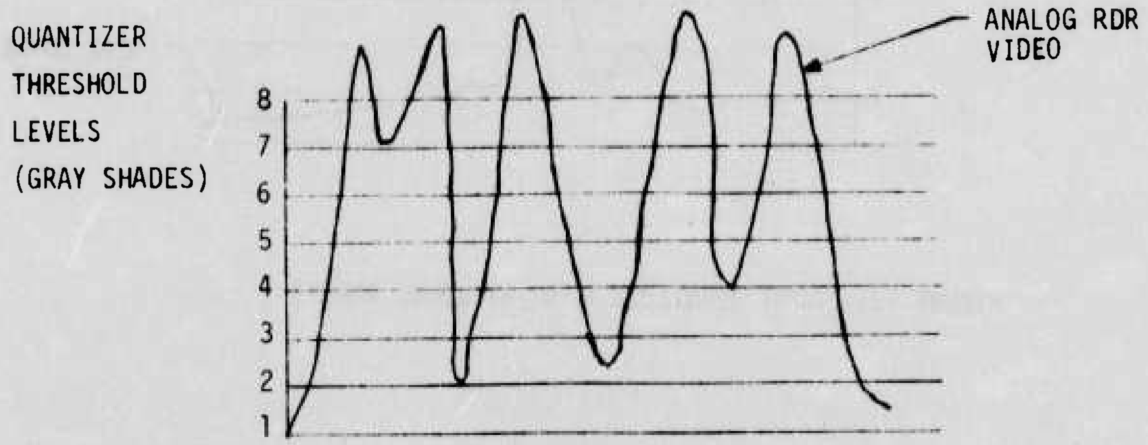

FIGURE 9. FIXED QUANTIZER WITH HIGH LEVEL RADAR VIDEO

The automatic quantizer function detects radar sensor peak noise, and raises or lowers the voltage range of the eight quantizer levels. In figure 10, the threshold levels are reduced due to low noise setting. All targets which exceed the threshold level will be displayed as bright returns. This illustration is typical of an air-to-air mode of operation. In Figure 11 strong air-to-ground mode returns move the threshold up. The quantizer levels are spread over the entire video range, giving maximum video returns. It should be noted, that maximum video level is determined in both cases by the quantizer. No display adjustment is required to maintain constant display intensity for the maximum signal return.

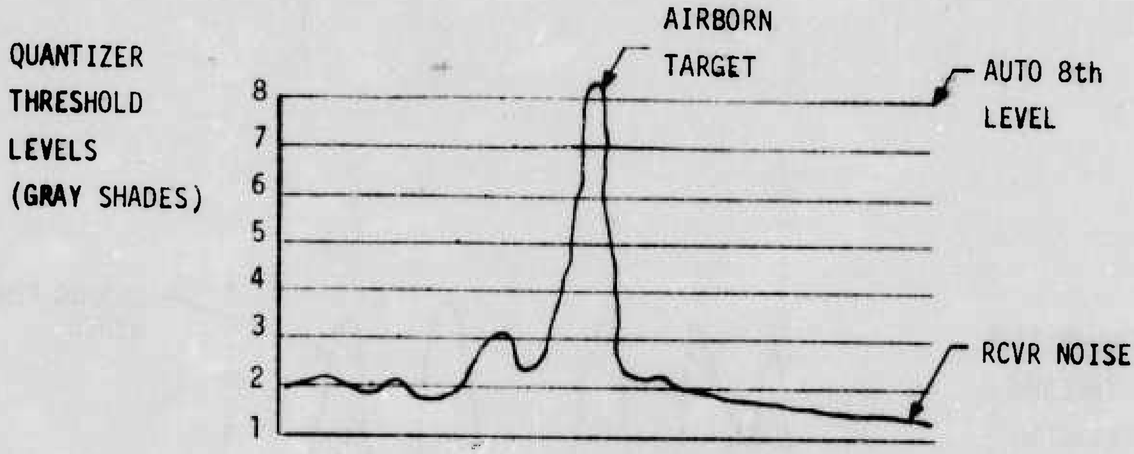

FIGURE 10. AUTO QUANTIZER WITH AIRBORNE TARGET

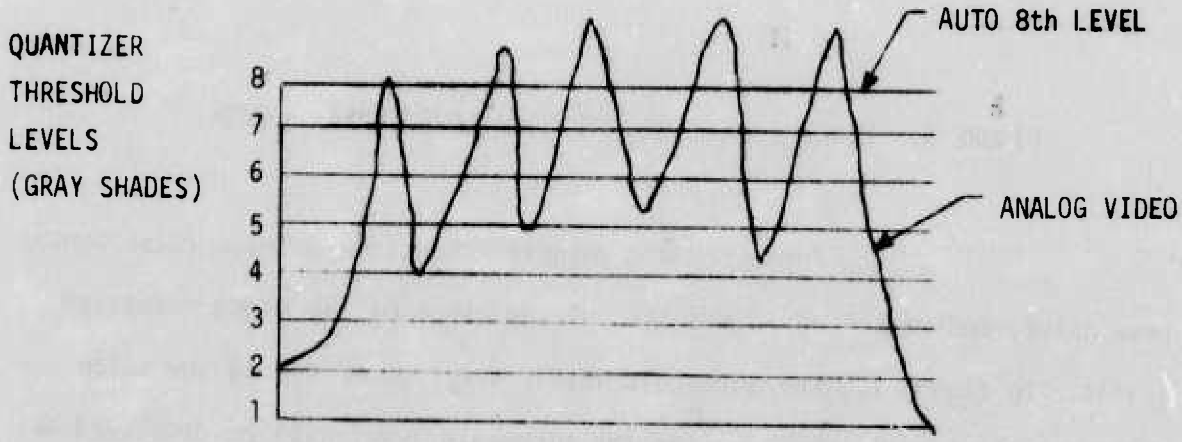

FIGURE 11. AUTO QUANTIZER WITH HIGH LEVEL GROUND MAP VIDEO

b. Quantizer Response

The basic quantizer response is a linear function. Printed circuit boards are designed and fabricated to yield non-linear, analog-to-digital conversion response, such as, log and inverse log.

c. Quantizer Frequency

The quantizer clock frequency is a function of range and is determined for each range by the following equation:

Where: f = quantizer range frequency

R = Radar range

These frequencies are derived by counting down from a basic 16.5652 MHz crystal-controlled clock. This master clock frequency allows the digital scan converter to be synchronized with the radar transmitter to within 30 nanoseconds, reducing jitter time to a negligible amount. The worse-case jitter-time occurs in the 5 nmi range - $\frac{30 \times 10^{-9}\ 100}{62 \times 10^{-6}} = .48\%$.

B. Symbology Generation

DSTUMDS symbology may be generated and displayed as either a dot matrix or raster video, or displayed as calligraphic or stroke written characters.

1. Video Symbology

Video symbol generation, mechanized as a digital dot matrix, yields the most accurate means of symbol registration to reticle overlays and raster video. Also, implementation of this approach easily lends itself to the generation of the display overlay as an electronic reticle removing all CRT display inaccuracies. The approach is rejected for the following reasons:

a. In order to fully utilize dot matrix symbology, an X-Y raster scan must be utilized. This requires a rho-theta to X-Y coordinate conversion with an attendent degradation of the radar sensor PPI mode. Even if a double memory capacity were possible, considerable doubt exists as to whether the PPI mode would be non-degraded.

b. If an X-Y raster mechanization is not used, the read PPI spiral scan CRT coverage precludes simultaneous display of the horizon line and elevation strobe symbols, except as calligraphic characters.

c. The hardware count, to achieve the digital dot matrix symbol generator, is estimated to require approximately 100 more integrated circuits than the alternate approach.

2. Calligraphic Symbology

Calligraphic symbology generation presents a simple implementation with a low component count. Since the multiplexed symbol mechanization has been proven on the Texas Instruments Incorporated, AN/APQ-100(XA-1) display group, low technical risk is incurred. The accuracy of calligraphic symbol generation is about three percent less than that of the raster video symbol generation. However, this is still within the requirements of the MacDonnell Douglas Specification, 53-870080.

In order to minimize circuitry, the symbols are generated in one circuit, which can be switch-logic connected to act as, either horizontal and vertical integrators for straight line characters, or as a linear differential amplifier for curved line characters. The basic memory timing was selected as the primary multiplex control; again as a method of reducing the required circuitry.

C. Power Supplies

1. Low Voltage DC Power Supplies

The DSTUMDS regulated DC power supply voltages are derived from three-phase, voltage rectifiers. The primary design considerations, relating to the supply voltages, are regulation, stability, and fold-back current limiting. State-of-the-art integrated circuits exist, which when used in conjunction with discrete series pass buffer transistors yield a $\pm 1\%$ regulation over the load and temperature conditions.

The fold-back current limiting feature reduces the series pass regulator transistor power dissipation under short circuit stress. Employing this technique yields high system reliability by fast action overload control. Additionally it prevents serial failures to the power supplies and other circuitry. Magnetic deflection systems are susceptible to power supply noise induced by other aircraft systems and poor aircraft grounding. In order to reduce such effects, each indicator contains its own sweep deflection power suppies.

2. High Voltage Power Supplies

The high voltage power supplies, utilized for DSTUMDS CRT operation, were selected from units which are utilized on other Texas Instruments Incorporated production programs. The units selected have exhibited stable characteristics and proven reliability in high volume production.

D. Electro-optical Performance Considerations

The F-4E TISEO sensor presents the worse-case DSTUMDS electro-optical sensor requirement. The cathode ray tube spot size, video amplifies bandwidth, and monitor dynamic range parameters must meet the TISEO minimum parameters.

The active sweep time for a standard 525-line, 60 Hz format is 54 usec. A 1 MHz square-wave signal, superimposed on this active sweep time, yields 54 white and 54 black, or 108 TV line-per-MHz. A 1000-line display, by this criterion, then requires $\frac{1000 \text{ lines}}{108 \text{ lines/MHz}} = 9.25$ MHz, bandwidth. The design objective of the video amplifier bandwidth was established at this value. However, as a result of later evaluations, this value is now 10.5 MHz.

The cathode ray tube spot size is a design trade-off between the TISEO and radar mode of operation. Smaller spot sizes, of course, yield higher electro-optical resolutions, but at the same time reduce radar symbol width. A .005 $\pm$.001-inch CRT spot size is considered optimum to fulfill both electro-optical and radar mode operation.

E. Thermal Design

The volume of cooling air for each LRU was calculated on the basis of maximum specified cockpit temperatures and subassembly power dissipation.

Average surface and mean ambient temperatures are outlined in Table 1.

TABLE 1

DSTUMDS Thermal Design Considerations

Assembly	Estimated Dissipation (Watts)	Inlet Temperature (^oF)	Outlet Temperature (^oF)	Mean Ambient Air Temperature (^oF)	Average Surface Temperature (^oF)	Calculated Pounds-per-Minute (lbs)	Required SCFM (13.5 CF/LB)	Fan Count	Fan Performance CFM each	HEAD "H2O"
P. I.	150	160	170	165	175	3.7	50	2	30	.25
R. P. F.	150	160	170	165	175	3.7	50	2	30	.25
AICU	330	160	170	165	175	8.0	108	2	56	.25

SECTION V

RELIABILITY/MAINTAINABILITY PROGRAM

A. Reliability Activity

The reliability activities undertaken during the DSTUMDS development were design assurance, reliability prediction, and burn-in support. Although no formalized reliability program was documented, a full-time reliability engineer was assigned to the program.

1. Design Assurance

The purpose of the design assurance activity is to establish reliability guidelines for equipment design. These guidelines ensure that equipment operational and environmental requirements can be achieved. Although broad in scope, design assurance covers detailed areas such as parts selection, parts application, parts derating, circuit layouts, thermal considerations, and environmental considerations. The reliability engineer is an integral part of the design team. He actively participates, not only in detailed circuit design, but also in design reviews and drawing approval cycles.

The effectiveness of this activity is reflected in the low number of problems experienced in burn-in testing and equipment field operation to date.

2. Reliability Prediction

The initial mean-time-between-failures (MTBF) prediction is based on system component count at the 80% design completion point, and an ambient temperature at +55°C on a maximum device case rise of 65°C. The

failure rate assigned to the MOS RAM devices at that time was $.5 \times 10^{-6}$. As the design progressed, engineering assessment of the actual equipment environment indicated that a worse-case ambient temperature of +71°C could be encountered, which in turn, would elevate RAM MOS case temperature to as high as +80°C. With these facts at hand, a decision was made to change the MOS RAM chip failure rate to 4×10^{-6}. Discussions with various semiconductor manufacturers showed that although such a failure rate is pessimistic, the value certainly represents a worse-case limit. Reevaluation of the MTBF, under the new failure rate constraints, yielded a prediction of 684 hours. It should be noted that the calculation assumed standard derating of 50% at a maximum +80°C temperature. No attempt was made to base failure rates on actual component stress levels, which in most cases, is less than the 50% assumption.

The 684 hour prediction was reviewed by reliability personnel from Rome Air Development Center (RADC). The review consisted of an independent prediction calculation and an audit of the program reliability controls and reliability activities. The RADC MTBF calculation showed a predicted MTBF of 473 hours. The primary differences in the RADC prediction lies in the allocation of higher failure rates to the RAM memory chips, the cathode ray tubes and the blower fans. Although Texas Instruments Incorporated considers the RADC prediction to be too conservative, the calculation does verify that the DSTUMDS predicted MTBF exceeds F-4E aircraft requirements.

3. Burn-in Test Support

In order to eliminate the infantile failures inherent in new equipments to stabilize the operating parameters, and to identify workmanship defects, a burn-in of the DSCG was performed prior to final test and shipment. This burn-in consisted of an accelerated temperature and vibration environment (-55°C to +54°C and intermittently to +71°C). The induced vibration consisted of a sinusoidal "G" amplitude for a period of ten minutes during each hour of operation. Approximately 100 operating hours in this environment were accumulated on the DSCG. Other than random infantile failures detected during this testing, only one problem was discovered which was felt to be design related. This was a line receiver integrated circuit which was improperly terminated. Upon discovery of the problem, the device termination was changed and no more failure instances were observed.

B. Maintainability Design Considerations

No formal maintainability program was conducted during the DSTUMDS development. However maintainability considerations were brought to bear during the initial design phase. This effort was directed primarily toward mechanical packaging, LRU interface, and assembly interchangeability.

1. Mechanical Layout

LRU system interface and form factor are established by F-4E aircraft installation requirements. This left little leeway for configurating the equipment to optimum maintenance considerations. Such factors as assembly position and mounting were within the control of the design engineer. Care was exercised to place components for easy test, access, and disassembly.

a. Air Indicator Control Unit

All printed circuit board (PCB) assemblies are mounted in the AICU LRU upper bay. Figures 12, 13, 14, and 15 provide for pictorial examples for referencing with this AICU LRU discussion. Easy access is possible by the removal of the PCB upper bay cover. All AICU printed circuit boards contain tests points at the cover end of the PCB. This allows troubleshooting and fault isolation without board removal. PCB fault isolation, to the component level, is made possible by the use of extender cards and an oscilloscope. The etched circuit boards in the AICU contain component symbolization to facilitate fault isolation, as shown in Figure 16.

Space and cooling constraints dictated that the AICU power supply heat sink, transformer and line filters be mounted in the AICU lower bay. Easy access to these components is provided by the AICU hinged back cover. The thermal design of the unit allows normal system operation with no overheating with the back cover removed.

b. Indicators

The mechanical layout of both indicators provide unobstructed access to the printed circuit board assemblies. Figures 17, 18, 19, 20, 21 and 22 provide pictorial examples for referencing with this Indicator LRU discussion. All indicator adjustments are located on, or near the access door-end of each PCB. All PCB components are symbolized to facilitate component fault isolation. The use of PCB extenders aid in assembly troubleshooting with an oscilloscope.

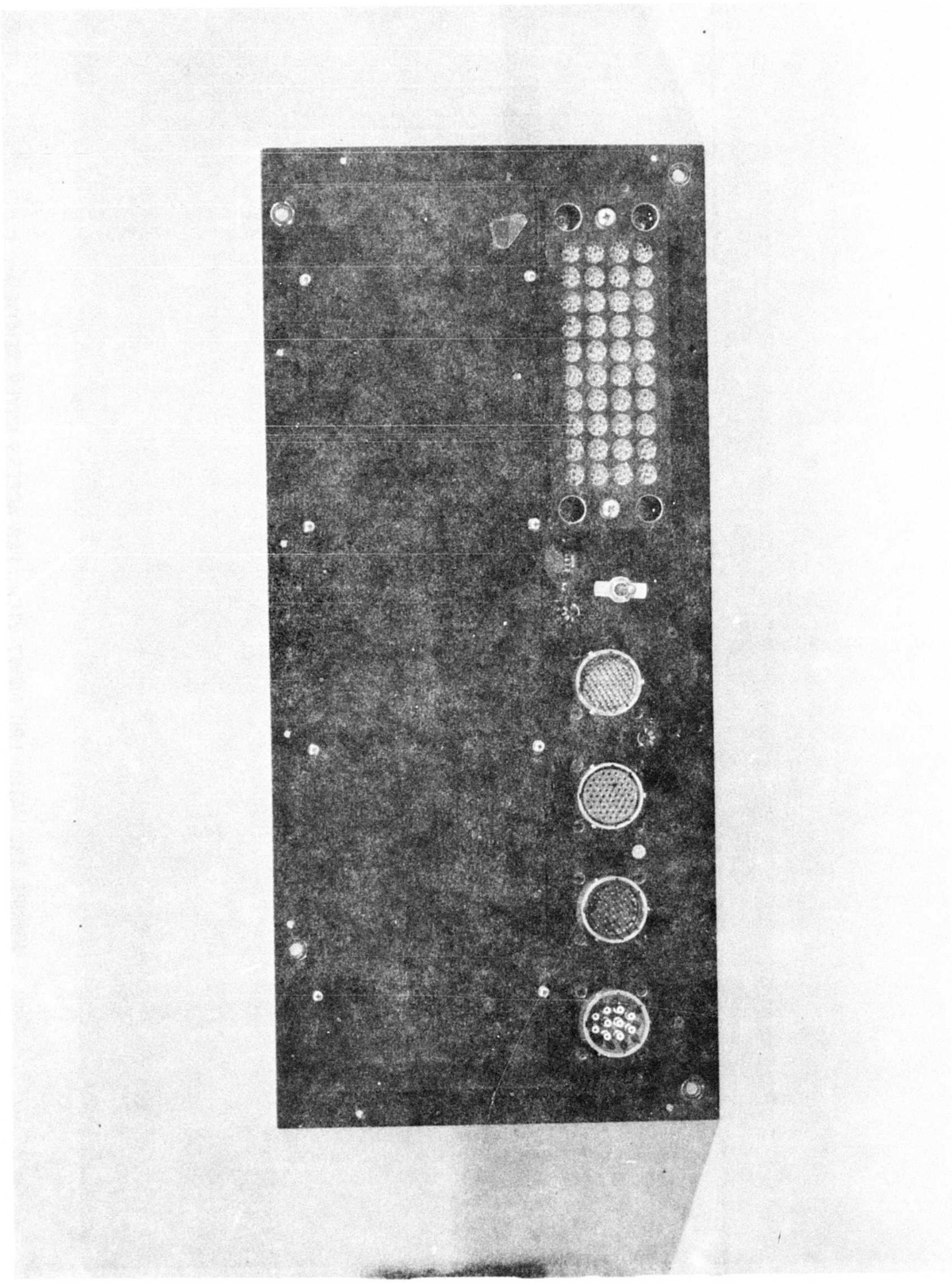

FIGURE 12. AICU LRU FRONT VIEW, COVERS INSTALLED

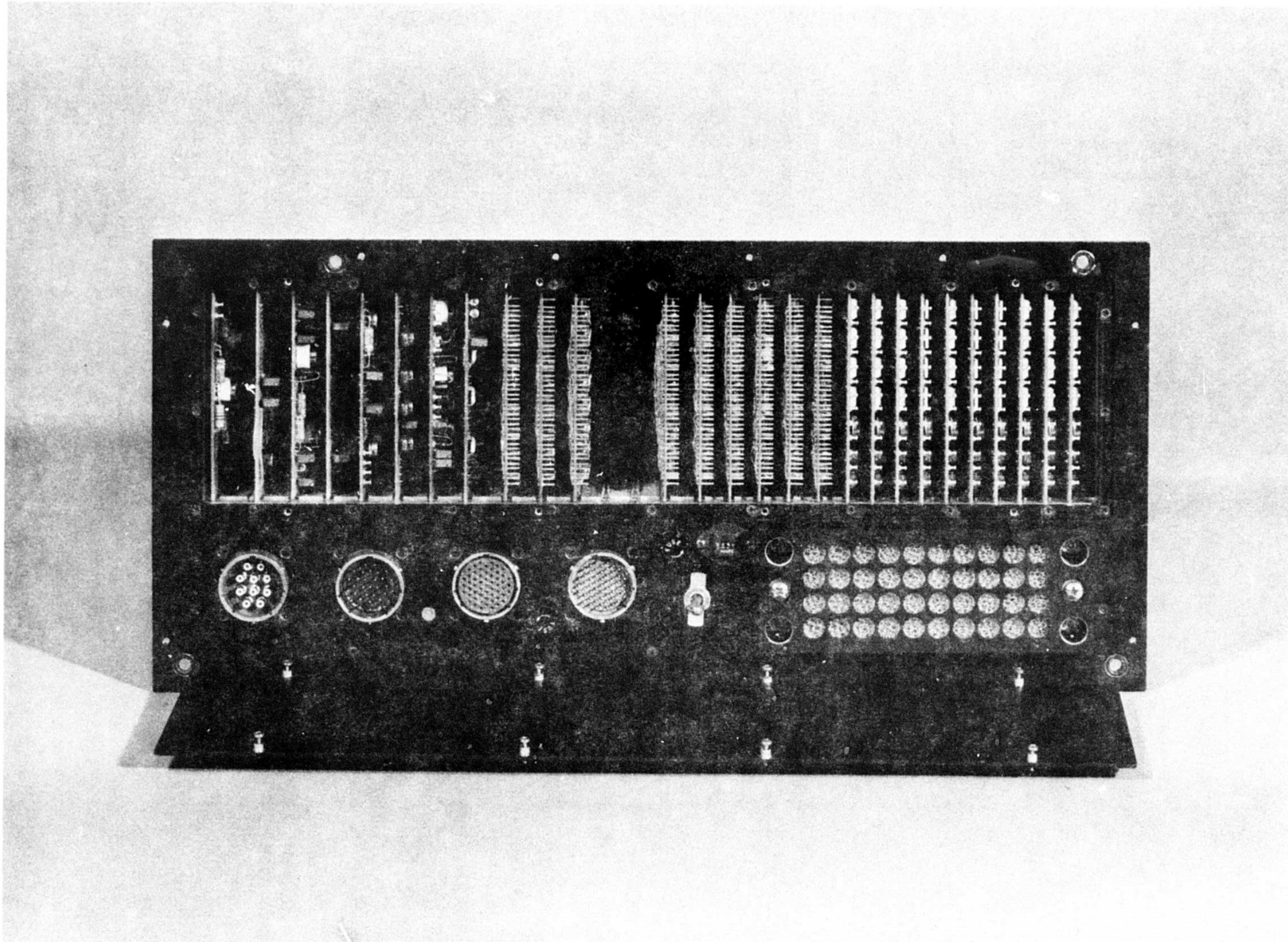

FIGURE 13. AICU LRU FRONT VIEW, PCB ACCESS COVER REMOVED

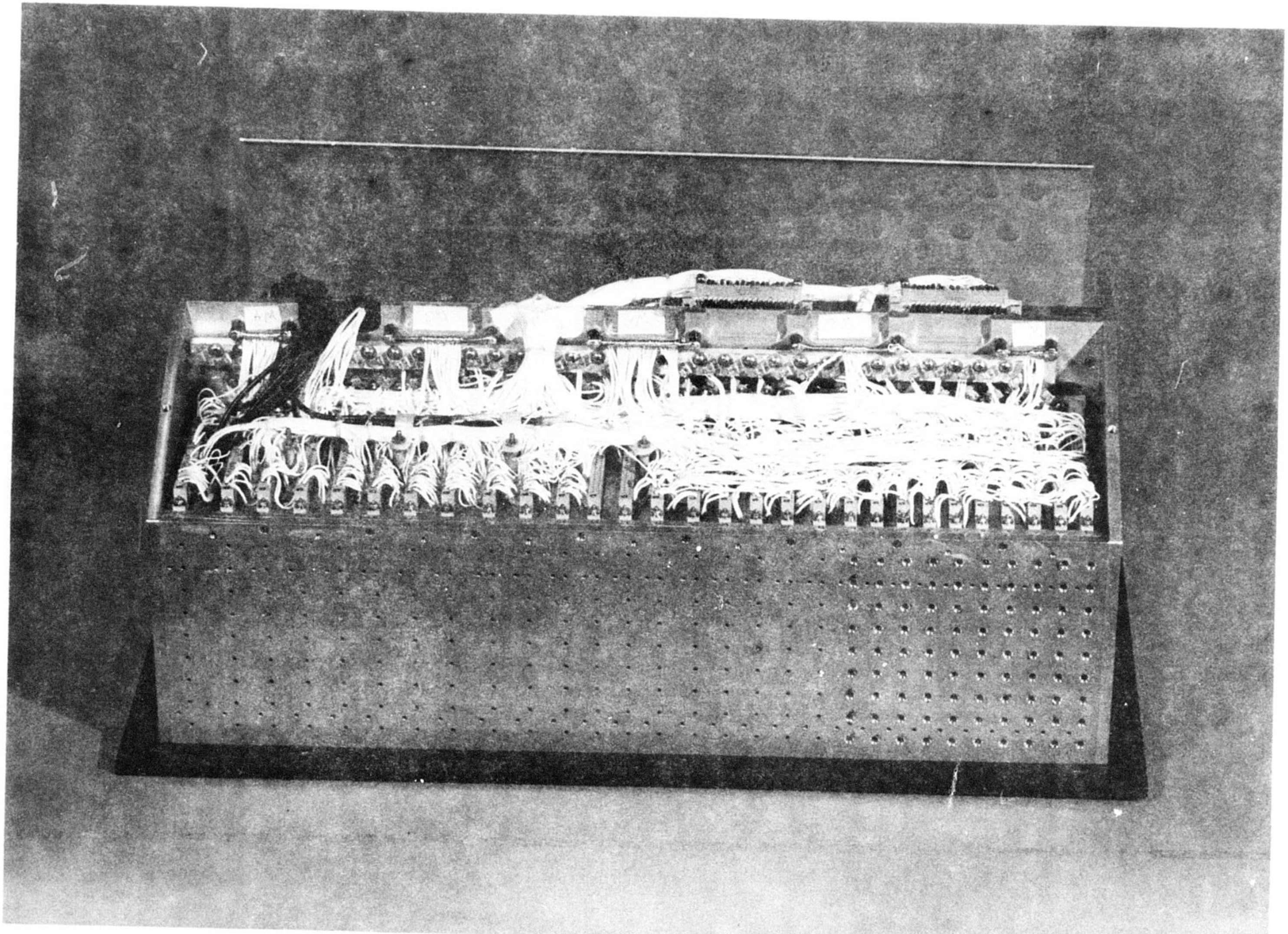

FIGURE 14. AICU LRU TOP VIEW, REAR COVER UNLATCHED

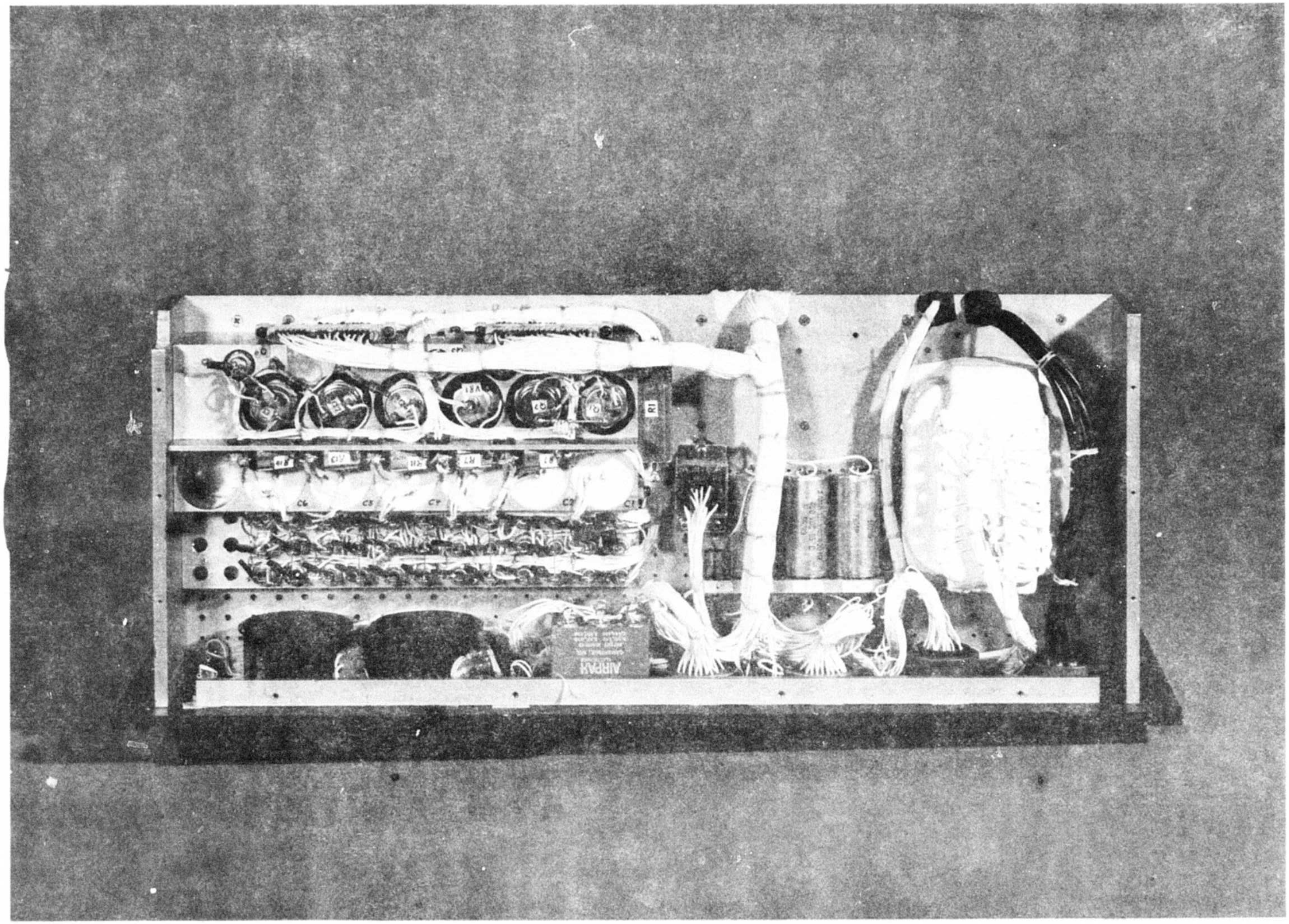

FIGURE 15. AICU LRU BOTTOM VIEW, REAR COVER UNLATCHED

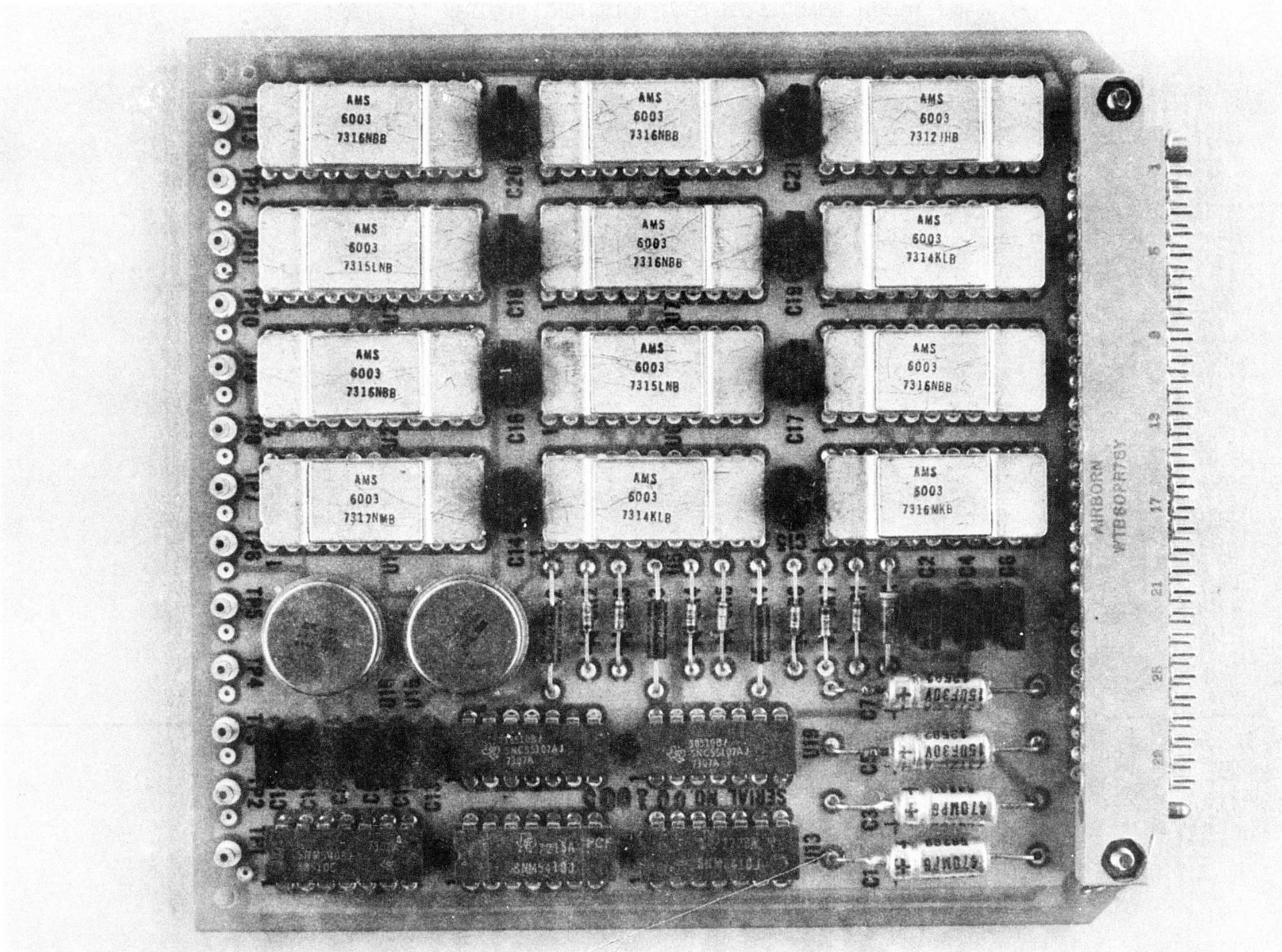

FIGURE 16. AICU MEMORY PRINTED CIRCUIT BOARD

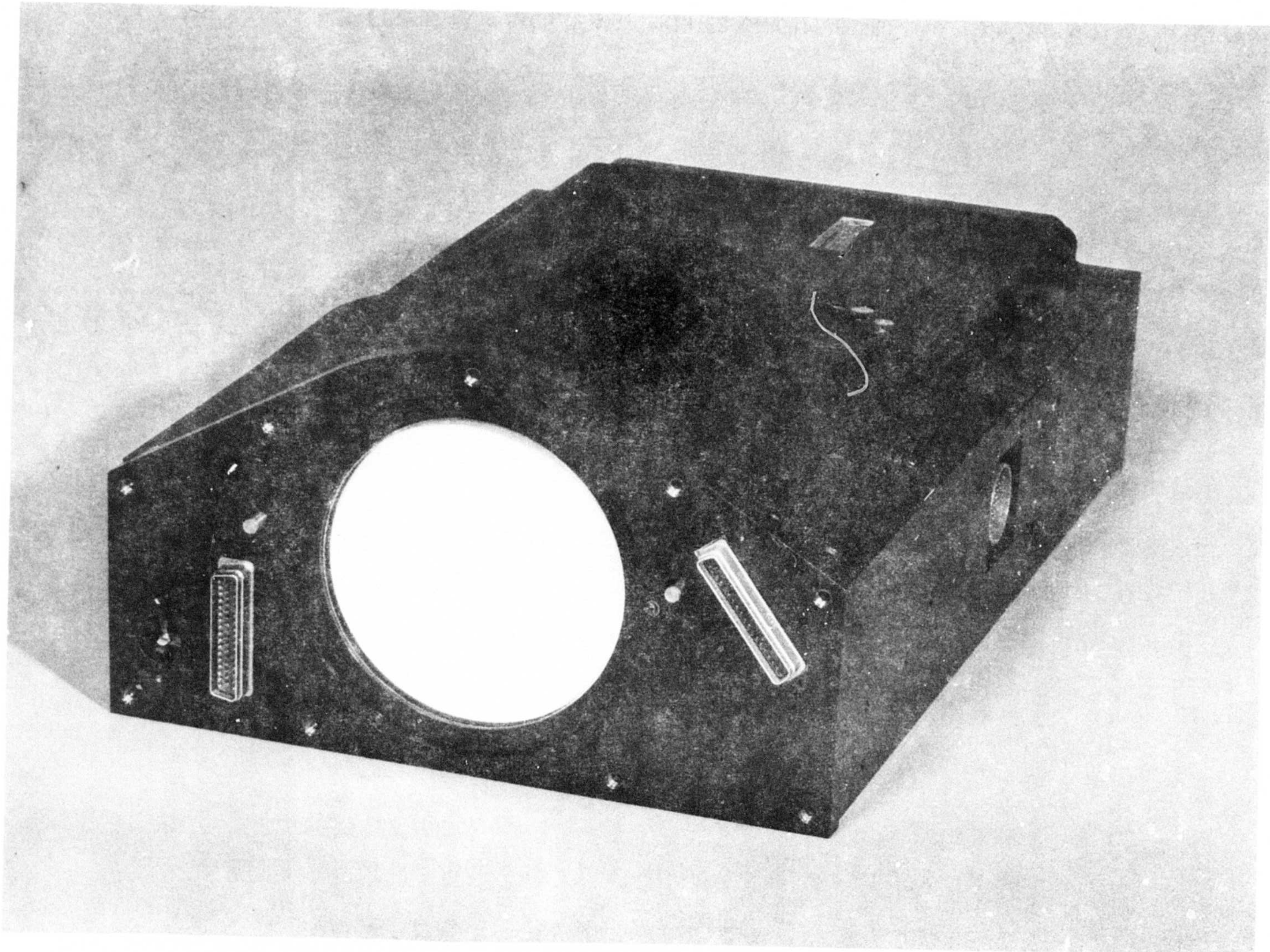

FIGURE 17. PILOTS INDICATOR LRU, DUST COVER INSTALLED

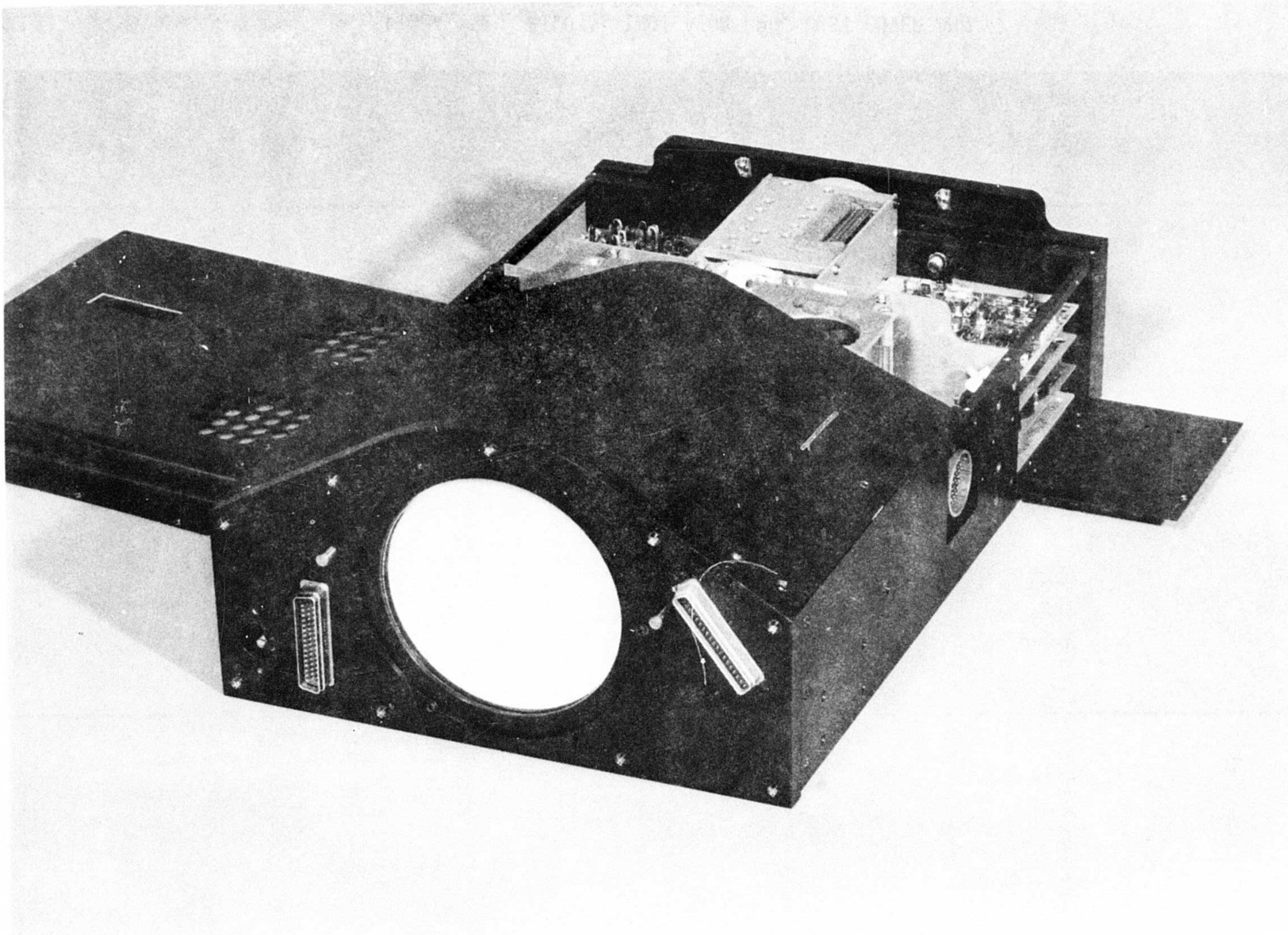

FIGURE 18. PILOT'S INDICATOR LRU, REAR DUST AND PCB ACCESS DOOR REMOVED

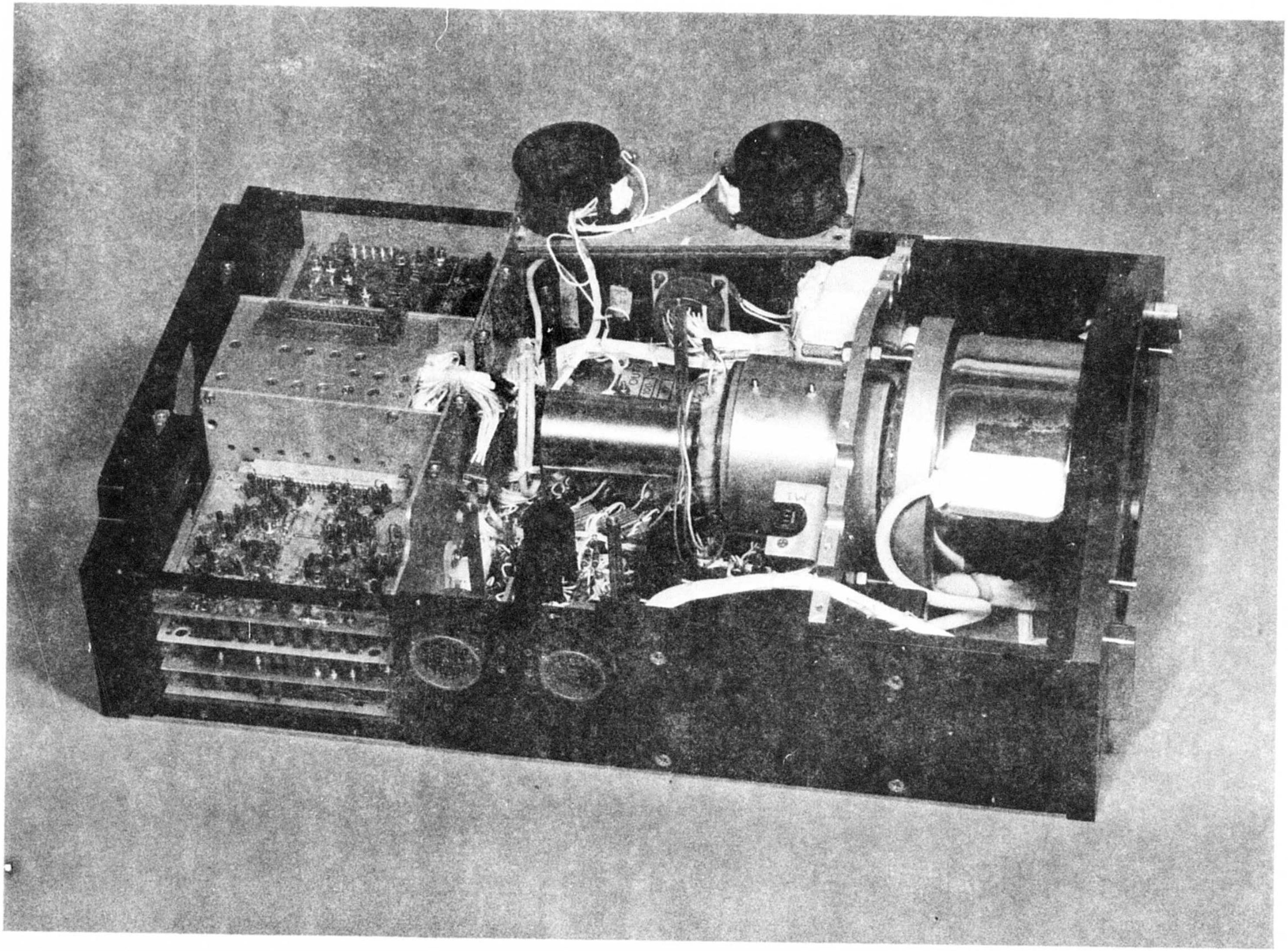

FIGURE 19. PILOT's INDICATOR LRU, DUST COVER AND ACCESS DOOR REMOVED

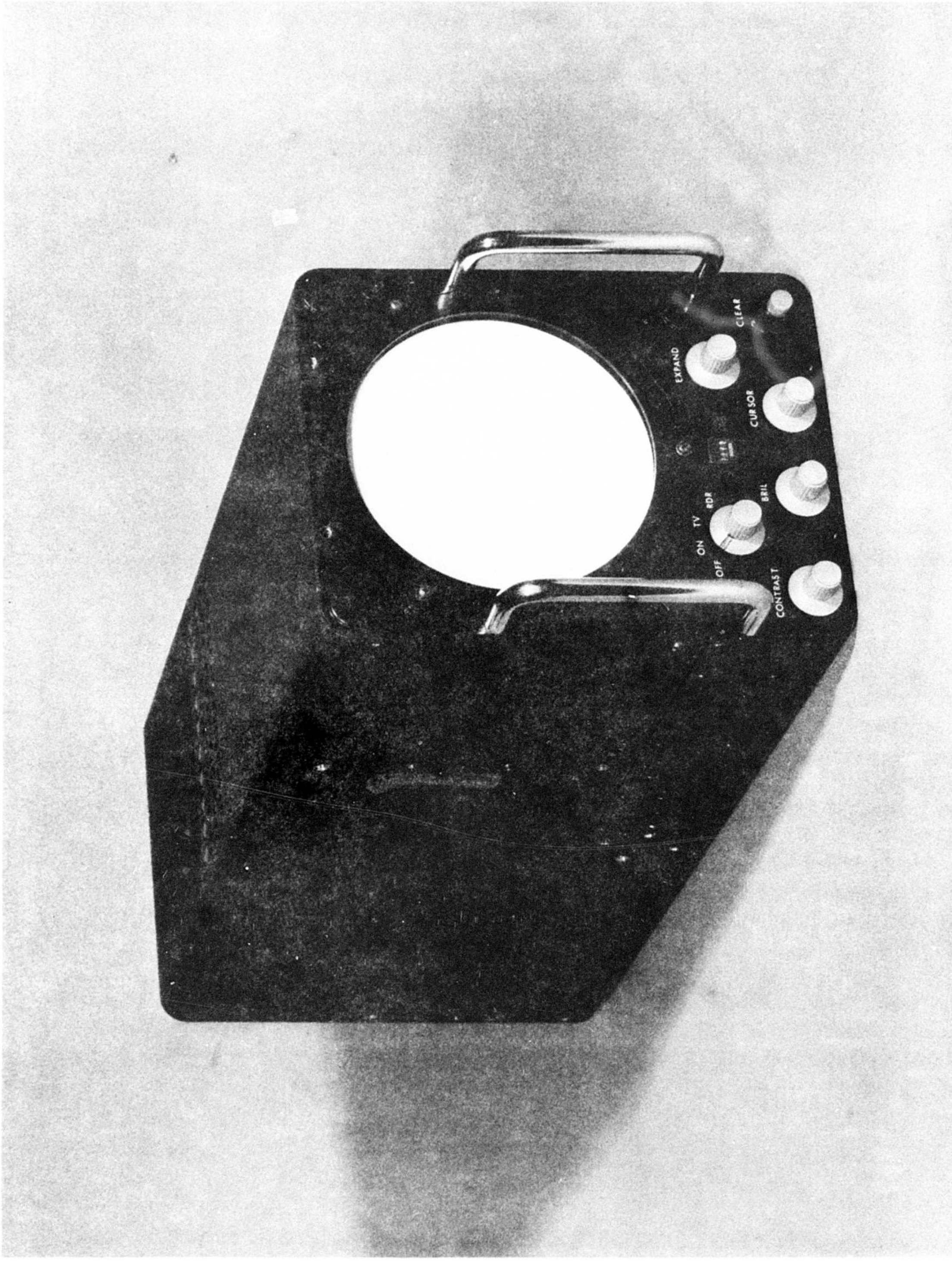

FIGURE 20. RADAR PILOT'S INDICATOR LRU, DUST COVERS INSTALLED

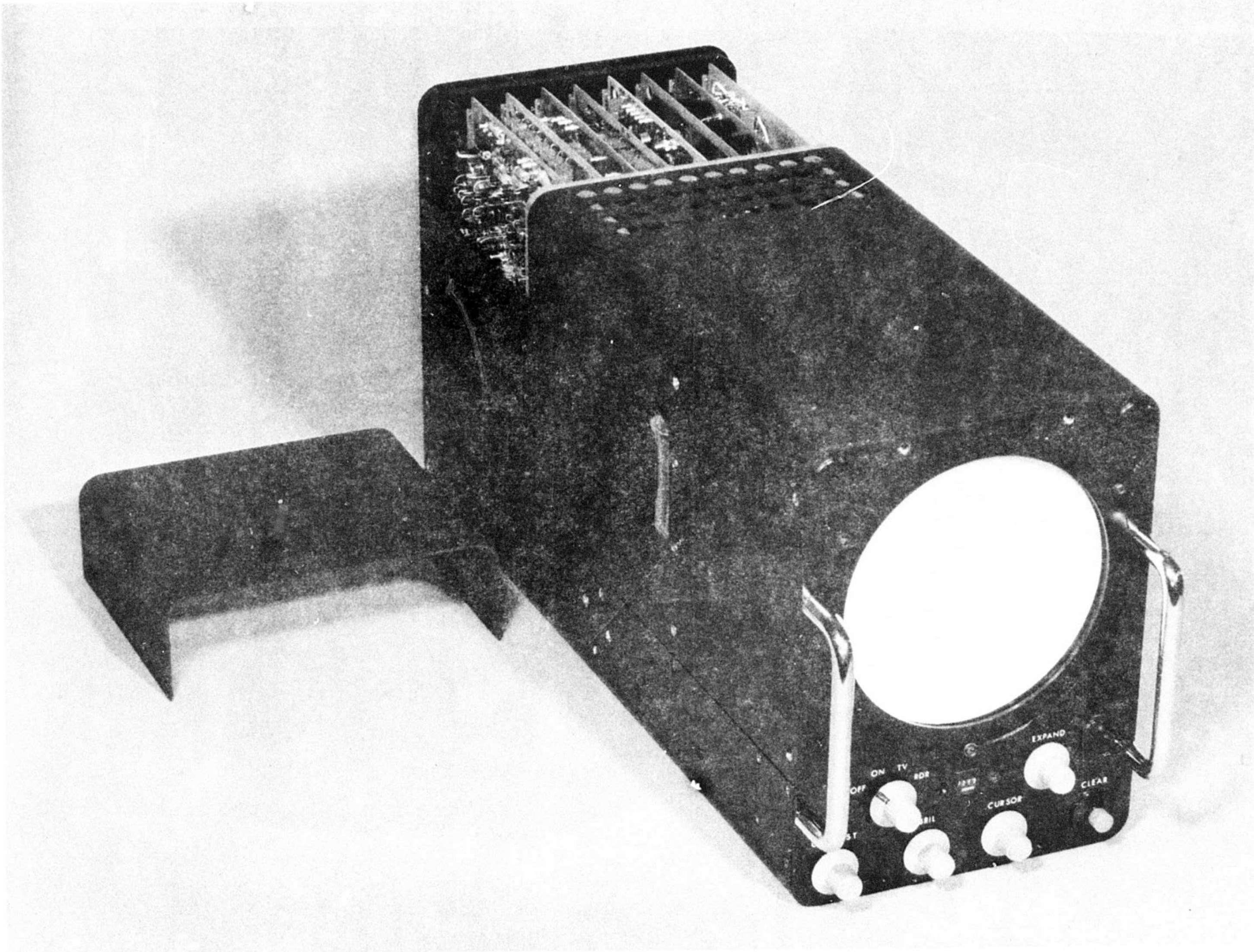

FIGURE 21. RADAR PILOT'S INDICATOR, PCB PANEL REMOVED

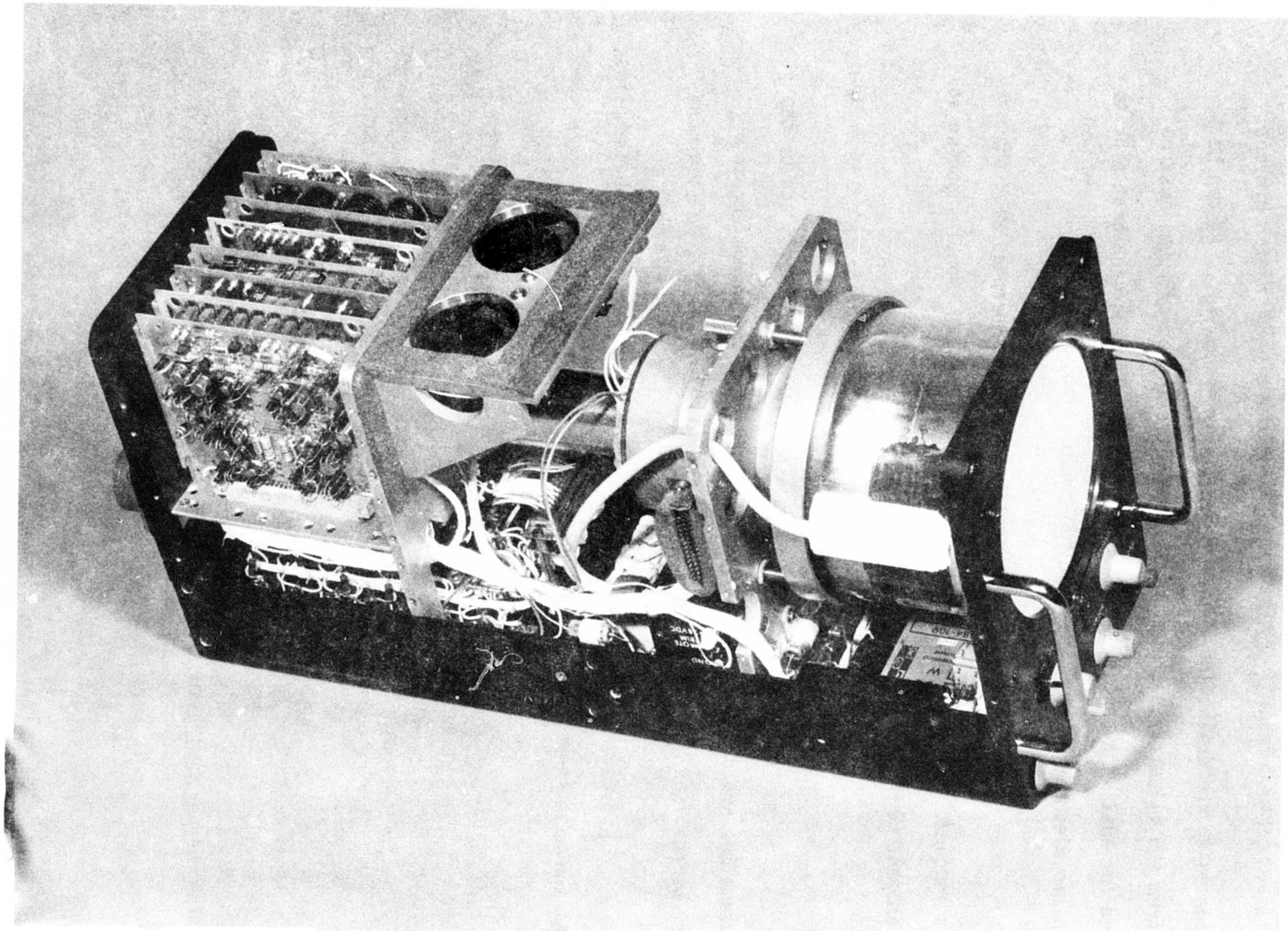

FIGURE 22. RADAR PILOT'S INDICATOR LRU, DUST COVER AND PCB ACCESS PANEL REMOVED

Form factor constraints and thermal design prevent easy access to the deflection/regulator heat sink assemblies. As can be seen from the illustration, both the PI and RPI cathode ray tubes must be removed for heat sink access. Test points are provided on each heat sink to aid in troubleshooting and component fault isolation.

The indicator LRU's can both be operated with the covers removed. No undue heat rise is experienced in LRU troubleshooting at room ambient conditions.

2. Subassembly Interchangeability

The AICU contains 30 subassemblies. Of these, ten of the subassemblies are directly interchangeable. These units random access memory boards, can be interchanged with no requirement for system alignment.

Each indicator contains 18 subassemblies. All subassemblies, except the heat sinks, are interchangeable between indicators.

SECTION VI

TESTS PERFORMED

A. Design Investigations

A number of design investigations were formed prior to contract award. This was accomplished to aid in component and circuit performance analysis.

1. Random Access Memory

A series of tests were performed on the AMS 6003, random access memory chip, to verify specified performance under the DSTUMDS environmental constraints. One memory plane, or printed circuit board, was constructed and subjected to a series of temperature tests and thermal shocks. The unit was thermally shocked, with operating voltage applied for 36 cycles; each cycle consisted of one hour at +85°C followed by one hour at -54°C. At the end of the thermal shock, the circuit passed all required performance tests at room temperature. Circuit performance was tested over a 0 to +55 degree centigrade temperature range and was found to be satisfactory. This temperature range was extended from -40 to +85 degrees centigrade; again, no performance degradation was noted. The sample size tested was 12 RAM chips which were all that were available at the time of test.

2. Cathode Ray Tube and High Voltage Power Supplies

A test fixture was constructed to evaluate high brightness, cathode-ray tubes and associated high voltage power supplies (HVPS). The purpose of the test was to evaluate the following:

CRT performance characteristics

CRT/HVPS interface

CRT operation in specified environments

a. CRT Performance Characteristics/HVPS Interface

Cathode-ray tube spot size, light output versus drive voltage, dynamic range, and focus control parameters were measured using a Venus, 20 kV power supply; the Tecnetic, +2500v focus supply; and a Tecnetic, +500v bias supply. Under the test conditions, the tube was found to exhibit the following characteristics:

Spot size	- .005±.001 inches
Light Output	- 1000 foot-lambert, minimum with a 3.5 X 3.5-inch, 525 line, 60 Hz raster at 50 volt grid-to-cathode drive voltage.
Contrast ratio	- 100:1 in a 1 foot-lambert, light environment.

The power supplies, selected for use with the CRT, exhibited no overload or stress conditions. Tests were performed on a sample of two Westinghouse, WX32427P58 CRTS.

b. CRT Environmental Evaluation

The CRT was tested under the following environments:

Vibration	- 2G's 5-500 Hz (longitudinal plane)
Shock	- 11G's 15 milliseconds (longitudinal plane)
Altitude	- 0-50K feet (operating)

A sample of two CRT's was evaluated. In addition, two half/mirror CRT's of the same type were also evaluated; one in vibration and shock; and one in altitude tests.

3. Low Voltage Regulators

Breadboard versions of the low voltage regulators were extensively evaluated for regulation and short circuit protection. Operation of the devices was tested over a -54 to +100 degrees centigrade range, exhibiting a worse-case regulation of ±1%. Fold-back current-limiting tests showed short-circuit protection to be fully operative within 50 microseconds under all temperature extremes.

4. Stitchweld Printed Circuit Boards

The stitchweld PCB process has been extensively used on a number of U.S. Navy contracts at Texas Instruments Incorporated. Although the technique has been proven, a series of tests were devised to evaluate the exact form-factor and wire configuration to be used on the DSTUMDS. Four representative PCB's were constructed and electrical components were mounted. These PCB's were then subjected to 124 hours of continuous thermal shocks, varying from -54 to +100°C, followed by 10G vibration from 5-20000 Hz, in a normal to the stitchweld connection plane. Units were visually inspected, following each test, to determine if wire breakage, cold welds and mounting terminal creeping were evident. Although some component solder connections were found to be faulty, no defects in the stitchweld was detected. It was concluded that the process in DSTUMDS configuration presents no technical risk.

5. Other Evaluations

No preliminary design investigations were conducted on the DSTU control circuitry, the symbol generator, or the indicator circuitry. The reason being that these functions had been evaluated in other Texas Instruments Incorporated display equipment and present no technical risk.

B. Subassembly Tests

Prior to their incorporation into its functional unit, each system subassembly was visually examined for workmanship faults and extensively electrically tested to verify performance. A minimum operating time of three hours was allocated to each unit. Those subassemblies, which contained MOS devices, were burned in at room temperature, with operating voltage applied for a period of 72 hours. Subsequent to this burn-in process, the units were performance tested. All high voltage power supply units were subjected to a 72-hour thermal shock of -54 to +100 degrees centigrade. All cathode ray tubes were altitude tested, operating to 50,000 feet.

C. System Tests

Three types of system tests were performed on the equipment. These were LRU performance testing, system performance testing and system burn-in.

1. LRU Performance Tests

These evaluations were performed at room temperature to verify the desired LRU performance. No environmental tests were attempted at this test level.

2. System Integration

The three LRU's, AICU, PI and RPI were integrated to form the DSTUMDS. Once integrated, they were evaluated with the aid of a system test set or signal input simulator. At this time the system elapsed time count began. DSTUMDS performance was critically evaluated and necessary system changes were incorporated. The tests were accomplished over a one week period, accumulating over 50 operating hours.

3. System Burn-in

The DSTUMDS was subjected to a chamber environment of -54 to +55 degrees centigrade on a two hour cycle. A ten-minute, 1G, 60 Hz level, vibration test was performed once each hour. The purpose of the test was to isolate and identify workmanship and/or design problems. No extensive performance evaluation was conducted during this period. The burn-in process was completed in a one week period. A total of 100 operating hours were accrued on the system.

D. Safety of Flight Tests

The purpose of the safety of flight tests was to certify flight worthiness of the DSTUMDS. The test included temperature/altitude, shock, vibration and explosion testing. All tests were performed in accordance with MIL-T-5422F(AS), 30 November 1971.

1. Temperature/Altitude

The temperature/altitude test profile is as follows:

STEP	AMBIENT TEMPERATURE	ALTITUDE	TOTAL TIME AFTER STABILIZATION	REMARKS
1.	-25°C	Ambient	2 hours	Non-operating
2.	0°C	Ambient	5 minutes	Operating
3.	0°C	30,000 ft	5 minutes	Operating
4.	+55°C	Ambient	4 hours	Operating
5.	+40°C	30,000 ft	4 hours	Operating

2. Vibration

Each DSTUMDS LRU was vibrated in the plane perpendicular to the printed circuit board mounting plane. Vibration profile is as follows:

(a) Resonant modes were defined by a resonance survey over the frequency range specified by Figure 23. All resonances were noted.

(b) A ten minute vibration dwell at each resonant point was performed with equipment operating at input levels defined by Figure 23.

(c) The equipment was vibrated, operating for two periods of 30 minutes, while subjected to 15-minute cycles over the frequency range and input levels outlined by Figure 23.

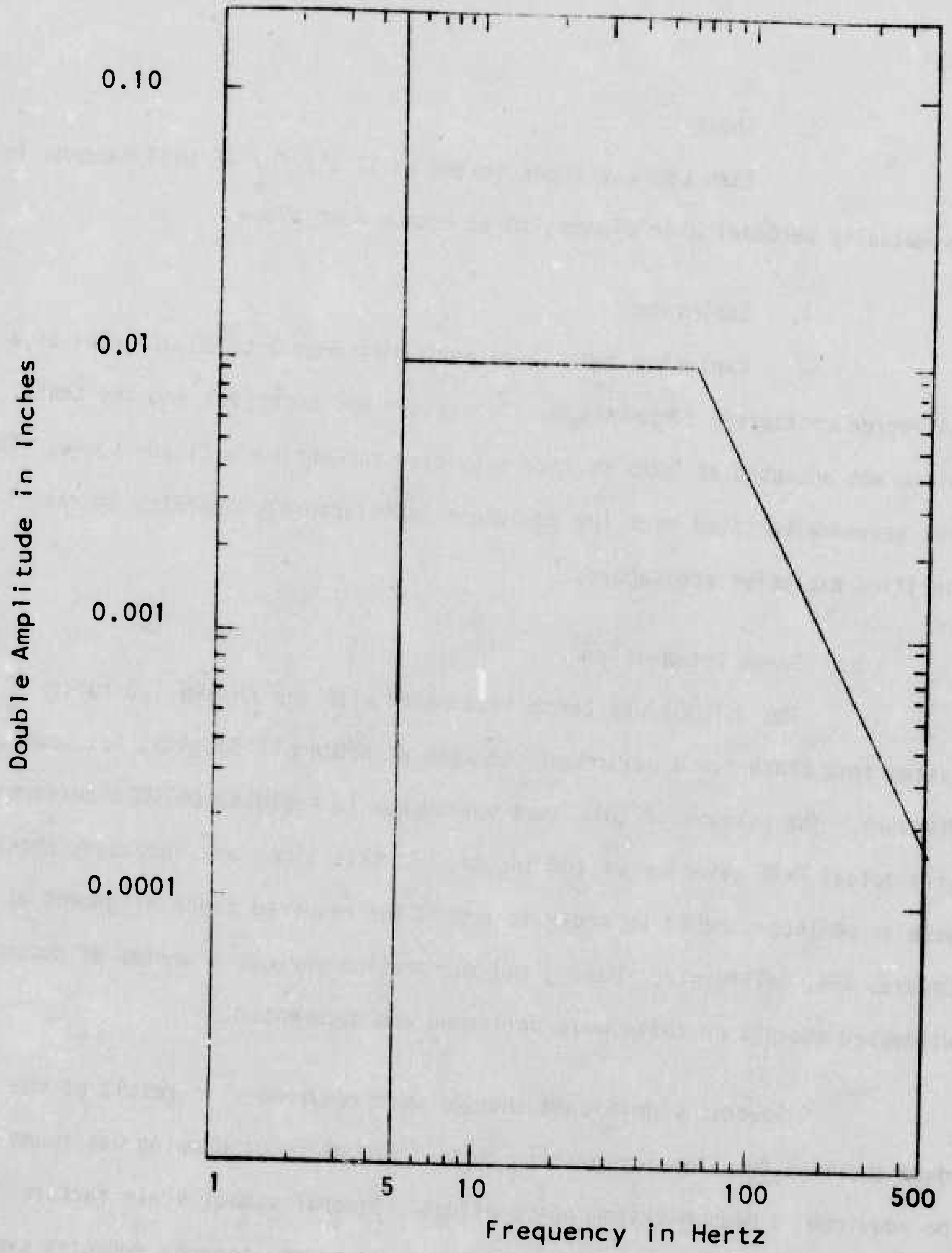

FIGURE 23. DSTUMDS VIBRATION LEVEL CURVE

3. Shock

Each LRU was shock tested at 11 G's for 15 milliseconds in six mutually perpendicular planes; three boards each plane.

4. Explosion

Explosion tests were performed from 0 to 30,000 feet at a +54 degree centigrade temperature. The system was energized and the test switch was actuated at 5000 ft intervals over the entire altitude range. This test sequence verified that the equipment satisfactorily operates in the specified explosive atmosphere.

D. Bench Integration

The DSTUMDS was bench integrated with the AN/APQ-120 radar system test bench for a period of one week at McDonnell Douglas, St. Louis, Missouri. The purpose of this test period was to evaluate DSTUMDS performance with actual F-4E avionics system inputs. At this time, any necessary changes were to be incorporated in order to reduce the required bench alignment at Edwards AFB, California. During the integration period, a series of customer witnessed acceptance tests were performed and documented.

Several significant changes were required as a result of the data obtained from the integration tests. Symbol input damping was found to be required to reduce system noise effect. Several symbol scale factors required attention to meet the specified performance, thereby reducing symbol brightness. Some system logic also required logic gate changes. However, a complete checkout of all mode logic was precluded by a bench failure.

F. Edwards AFB, California, Flight Test

No bench integration was performed. The system was directly installed in the F-4E test aircraft. The details of the flight test are outlined in a separate AFAL report and are not included in this report.

G. Nellis AFB, Nevada, Flight Test

Two flight test phases were conducted by the Tactical Air Command (TAC) at Nellis AFB, Nevada. The first phase consisted of a series of comparative flight evaluations between the F-4E DSTUMDS and the F-4E Multisensor Display Group (MSDG) display. In the second phase, a number of flights were conducted under AFAL direction. This was accomplished to evaluate several performance parameters of the DSTUMDS.

The details and conclusions of these flight tests are contained in a report published by the Tactical Air Command.

SECTION VII

PROBLEMS ENCOUNTERED AND SOLUTIONS IMPLEMENTED

This section addresses specific performance or design problems encountered in DSTUMDS development and the corrective actions which were taken.

A. Design and Initial Test Phase

1. Rear Indicator Tube Size

McDonnell Douglas Specification 53-870080, requires a usable display of 4.375 by 4.375 inches for the rear indicator display. The time required to cast a mold for the CRT, with the selected parameters, was a minimum of 16 weeks. This delivery was not commensurate with the program time-frame. The large tube was not available for use. Subsequent systems can utilize this larger tube, whose performance is identical to the front indicator devices, with no system implication.

2. Memory noise at High Temperature

In system burn-in at temperatures of +55 degrees centigrade and above, memory operation exhibited noise spikes which were visible on the cathode-ray tube display. The problem did not manifest itself in a single RAM chip test, or even on a single memory PCB test. Investigation showed that the basic problem resulted from memory driver pulse rise time increases with temperature. This high frequency signal was being cross-coupled into the memory chip through the RAM power supply lines. The stitchweld PCB mechanication prevented the use of separate B+ and ground planes. Although adequate decoupling could be achieved with passive components, this was not considered to be an adequate answer. The

second DSTUMDS fabricated, under contract F33615-73-C-1292, utilized multilayer memory boards which provide separate planes for each power supply voltage; no noise coupling problems are evident in this configuration.

3. Line Receiver Transient Immunity

The horizontal and vertical sync signals from the AICU are buffered at each indicator LRU with a line receiver integrated circuit. This device provides not only buffering, but restores sync signal rise and fall time which are degraded by the reactive elements of the aircraft interconnect cabling. During system burn-in, excessive voltage transients were experienced due to chamber compressor operation. These transients caused a number of line receiver failures. Diode input protection for positive and negative line spikes was incorporated. No further failures were experienced, even when spikes of 50 to 60 volts peak were induced on the signal lines.

4. Cathode Ray Tube Neck Shielding

In indicator LRU integration tests, 400 cycle interference problems became evident. The thickness of the Co-Netic CRT shield was found to be inadequate. The situation was corrected by increasing the shield thickness.

5. -15 VDC Power Supply Current Limiting

During DSTUMDS system check-out, it was discovered that the -15 VDC power supply regulator received sufficient load, under full system load during turn-on, to cause the current limiting function to actuate. The +15 VDC regulator first achieves full voltage. Then, in turn, it supplies sufficient loading on the -15 volt supply to keep the circuit from reaching full operating output. The only plausible solution is a +15

VDC power supply delay. At the time that the fault was discovered, it was deemed a technical risk to incorporate a +15 volt supply delay without extensive design analysis. In order to meet the equipment delivery schedule, the -15 VDC fold-back current limiting was removed and circuit protection was provided by a fuse on the front panel of the AICU LRU.

B. Bench Integration Phase

1. Cathode Ray Tube Protection Circuitry

The CRT Phosphor protection circuitry response was found to be inadequate to prevent phosphor burn during system mode changes. The circuitry was altered and the sweeps were AC coupled to slow the transmit response. This modification was later found to cause slow raster fly-in at Nellis AFB, Nevada.

2. Video Clamp

The initial DSTUMDS design utilized clamped video for both radar and electro optical modes. Bench integration tests showed that the automatic level control action, exhibited by the TISEO sensor, resulted in a gray shade or dynamic range loss with clamped video. The system was altered to yield clamped video in radar modes and unclamped video in TV modes. Tests with the Walleye and Maverick missiles showed no degradation due to the change.

3. Symbol Generation

Bench integration tests identified a number of scale factor and logic inconsistencies which were corrected. The most significant problem to be defined in this phase was the low frequency, F-4E system noise, which resulted in noisy symbology. The problem was solved by a decrease of the symbol generator low frequency response. No degradation in system

performance was evident as a result of the change. Symbology format evaluation by flight test personnel indicated that the symbol brightness was excessive. This level, which was one $\sqrt{2}$ gray shade brighter than all video, was reduced.

C. Edwards AFB, California, Flight Test Phase

1. Broken Aircraft Wiring

Installation and checkout of the DSTUMDS in the aircraft showed an aircraft cable wire to be broken. Repair was not possible, so the broken wire was moved to another connector pin. This necessitated a change in the internal wiring of the AICU.

2. Relay Failure

During the Edwards AFB, California, flight test, a relay failure was experienced in the RPI LRU. This failure resulted in an inability to switch the RPI LRU from radar to TISEO mode. An analysis of the failure indicated that insufficient contact current was used. All such relays were designed out of the system.

3. Radar Video Recording

A video tape recording of the radar video was not possible during this flight test phase. This was due to the fact that the raster video from the AICU did not contain horizontal and vertical sync data. Subsequent to the flight test, the DSTUMDS was modified to provide radar video recording, but recording of the calligraphic symbology was not practical.

4. No Narrow Scan Erase

The DSTUMDS design cannot accommodate memory erase for the radar narrow scan mode. The video in the narrow sector scan updates in the normal manner. However, no mechanization exists to automatically erase the stored data outside of the narrow antenna scan sector. The design modification, required to implement the automatic erase, consists of generating a video gate whose position and width coincide with the narrow sector scan. All data outside of this video gate is removed from memory. The mechanication requires memory control retiming. This task was not commensurate with the Edwards AFB, California, or later flight test schedules.

5. Incorrect B Strobe Scale Factor

In the course of the flight test, it was determined that the azimuth scale factor of the B strobe was incorrect. Fixed resistor values were changed to correct the deficiency.

6. EO Mode Display Brightness

Pilot comments indicated that the brightness of the TISEO display was less than was desired. The EO sensor video gain was increased prior to the test conducted at Nellis AFB, Nevada.

D. Nellis AFB, Nevada, Flight Test Phase

The results of the comparative flight tests between the DSTUMDS and MSDG are not availble to Texas Instruments Incorporated. The following paragraphs outline those problems which were defined as a result of maintenance debriefings, analysis of DSTUMDS video tapes, and communication with AFAL personnel concerning the AFAL DSTUMDS test flights. Other problems could exist, but are unknown at this time. In many

instances, system deficiencies could not be corrected due to flight schedule requirements. The corrections for such deficiencies are discussed in the recommendations section of this report.

1. Blank Scopes

A short on the +15 VDC line activated the regulator current limiting. The cause of the short was found to be a power transistor lead shorting to the AICU case. No component failures resulted. The transistor lead was electrically isolated.

2. No Reticle Lights

Edge-lit reticles have been fabricated, but not installed.

3. No HOJ Light

Edge-lit reticles have been fabricated, but not installed.

4. No Narrow Scan Automatic Erase

This problem has been previously discussed under the Edwards, AFB, California, flight test problems.

5. Slow Raster Fly-In

This deficiency manifests itself in mode change from TV to radar and results from AC coupled sweeps being implemented to prevent CRT burn.

6. Recorded Symbols

The radar symbology cannot be recorded due to its calligraphic mechanization. Both X and Y deflection signals are required for symbol display. This, in turn, requires either a multi-channel video recorder or symbol position encoding with a special playback unit.

7. Radar PPI Mode Playback

The DSTUMDS design provides a PPI mode by sine-cosine modulation of the memory read raster. The data from the AICU, that recorded in a B scan format, requires a special linear differential analyzer (LDA) generator to yield a PPI format. An X-Y monitor and a LDA sweep generator unit has been provided for radar mode PPI playback. In this manner, recorded video tape data is converted to a spiral scan PPI raster. Manual switch selection in the sweep generator yields either radar PPI, B scan, or 525-line, 60 Hz TV. Some difficulty was experienced with the X-Y monitor, precluding 100% utilization of the playback unit. However, such playback feasibility has been demonstrated.

8. Coast Line Detection

Evaluation of DSTUMDS video tapes showed a coast line detection problem due to sea clutter. The sensitivity and detection capabilities of the linear response quantizer is far greater than normal displays for low clutter signals. Such sensitivity causes the signal strength of sea clutter and coast line returns to be displayed only two to three gray shade levels apart at normal radar receiver gain settings. The target return response is then, to a degree, masked by the clutter. Classic black water and bright land returns detection cannot be obtained without drastically reducing the receiver gain. Experience with similar systems has shown that an inverse log response quantizer reduces DSTU sensitivity for low level signals, such as sea clutter, and at the same time maintains overall dynamic range. Such a mechanization was flown in a series of AFAL DSTUMDS flight tests. Positive results were obtained with coast line detection being increased drastically, as well as, clearly defined coast line-to-water contrast.

9. Antenna Azimuth Shift

Tape evaluations also showed that some radar systems exhibit target azimuth shift of about one azimuth bin. Further investigation of this phenomenon revealed the shift to be a function of individual radar system antenna gear box backlash. The azimuth shift of any radar system could be adjusted to zero shift by the antenna synchro-to-digital lead lag circuitry.

Although at some times confused with target azimuth shift, the video tapes also showed a gray shade differential between right and left antenna scans. Hard target returns remained constant, but cultural clutter changed. Again, the effect appeared to be apparent only on some radar systems. At this time, insufficient data exists to allow analysis. The possibility does exist that the effect is caused by an antenna side lobe which can drastically affect clutter appearance between opposite antenna scans.

10. Dim Targets in Radar Lock-on Modes

Pilot comments indicated a dimming, or reduced target intensity, between B scan search and lock-on. Measurement of raw radar video between the two modes showed that video level, does indeed reduce by radar automatic gain control (AGC) action in stop scan or lock-on. The problem was solved by mechanizing the threshold detect circuitry during lock-on modes to maximize target intensity.

11. Radar Antenna Shimmy in AGR Mode

Fault was found to lie in the "anding" of the AGR and BST signals in the DSTUMDS. This resulted in incorrectly sending a logic back to the radar system in the AGR mode. The "and" logic was removed.

The reason for late discovery of this fault is that the AGR function was inoperative on the MacDonnell Douglas test bench at the time of bench evaluation. The mode was not utilized in the Edwards AFB, California flight test.

12. Experimental Cathode Ray Tube

During the AFAL portion of the flight test, a mirrored CRT was installed in the RPI for test of its capability to improve contrast. In flight, intermittent CRT flickering was noted by the operator. According to the operator's report this intermittent situation continued for approximately thirty-five minutes prior to experiencing blank displays on both scopes. Inspection of the RPI showed the following failures: the CRT, a +40 V regulator transistor, and a +40 V regulator resistor failure. Accurate reconstruction of the primary failure cause is impossible. It is unlikely that random +40 VDC regulator failures would occur simultaneously in both indicators. It is just as unlikely that the possibility of a large power surge, such as transient would have caused failure in other power supplies. It is assumed that the primary failure occurred as internal arcing in the cathode-ray tube. This reduced transients in the deflection system and caused an overload with attendant current fold-back of the deflection power supplies. The deflection power supply in intermittent current limiting could cause intermittent current limiting in the +15 VDC power supply. This would affect both indicators. The fact that intermittent current limiting occurred for over a thirty minute period would have caused overheating of the +40 V regulator transistors. The unit is intentionally designed to cause failure of these components opening the high current lines as a safety feature, if for some reason current fold-back conditions are exceeded.

SECTION VIII

DSTUMDS PROGRAM RESULTS

The conclusion drawn from the extensive flight evaluation by the Tactical Air Command at Nellis AFB, Nevada are not known. This report cannot outline explicit quantitative results from that effort. It is possible, however, to draw conclusions concerning the development program, based on Texas Instruments Incorporated's engineering personnel participating in the Edwards Air Force Base, flight test; participating in maintenance debriefings at Nellis AFB, Nevada and participating in the test and evaluation of the DSTUMDS, compared to similar equipment built by Texas Instruments Incorporated.

A. Initial Flight Test

The limited flight test, conducted at Edwards AFB, California proved the feasibility of the DSTUMDS concept and its application for F-4E use. Quantitative data collection was not possible. Operational comments showed the system to be adaptable to F-4E radar, to sensors, and usable from an operational standpoint.

B. Memory Technology

The application of semiconductor random access memories to DSTU use was proved. The 2 K MOS chip performance was found to be adequate in extreme military aircraft environments. A specified temperature upper limit of +85 degrees centigrade was imposed on the device by its manufacturers, but temperatures well beyond this were experienced in the aircraft environment with no apparent degradation. It is conceivable that the device high temperature characterization could be changed to a higher

temperature level when used for DSTU application. Such knowledge could prove invaluable in the characterization of any future RAM devices. If the foregoing premise is valid, then selected device parameters criteria could be considerably broadened when used in digital signal processors such as the DSTU.

C. Reliability and Maintenance

The high reliability and long life of the DSTUMDS solid state design was demonstrated. In 62 data flights, only one failure was experienced. This failure, a relay, could have been avoided if the device had not been initially designed into the equipment to accommodate system 28 volt logic. Whether or not the transistor-to-case power supply short is attributed as a system failure is not known. However, it should be pointed out that no component failure resulted. The failure, induced by the experimental CRT in the AFAL flight, occurred during an engineering evaluation of a new device. This is not considered to be a failure which can logically be charged to the DSTUMDS prototype configuration.

Directly related to both reliability and maintenance, is the stability exhibited by the display system. Neither periodic maintenance adjustments nor LRU harmonization adjustments were required to maintain system performance.

Due to a lack of system failures, very little maintenance data was obtained from the flight test periods. A decided maintenance improvement over conventional analog systems has already been noted concerning stability.

D. Reduced Operator Work Load

The DSTUMDS provided a much reduced operator work load. This can be attributed to five basic factors. These are:

Separation of the storage and integration function

A flicker-free non-fade display

Bench adjustable radar and TV amplitude

Wide dynamic range CRT

The automatic radar quantizer

Separation of the storage and integration function removes the dependency of indicator intensity and contrast on storage time (radar display persistence). Because the data is read from a random access memory, the display format is non-fade and flicker-free. The very need for a persistence control is removed. These two factors combine to reduce required system adjustments and the operator attention span.

A bench adjustment is provided in the DSTUMDS to match video amplitude of both radar and elector optical data. Coupled with the wide dynamic range capability of the CRT, the need for operator adjustment between modes is drastically reduced, if not completely removed.

The action of the automatic quantizer maintains a constant signal level for any given receiver gain setting. This prevents the need for display adjustments between radar range changes (even operational modes, such as ground map to air intercept).

Sufficient TAC evaluation data is not available to determine if operator work load and usability is enhanced appreciably by the threshold detect and peak detect functions.

E. Radar System Performance

Comparisons made of radar performance using the DSTUMDS relative to the performance of the Texas Instruments Incorporated developed, direct view storage tube and analog scan converter displays, show the DSTUMDS superior in the following areas:

1. Digital integration prior to data storage improves the signal to noise ratio by a minimum of 3 dB. The mechanization of digital scan-to-scan integration can achieve signal-to-noise improvements of 9 dB, or greater.

2. The analog displays are limited in growth capability due to fixed vacuum tube parameters. The DSTUMDS can accomodate higher performance by the addition of memory.

3. The analog displays suffer resolution and dynamic range loss as a function of storage time. In the analog-to-analog conversion mechanization of the DSTUMDS, resolution and dynamic range are unaffected.

4. The DSTUMDS design is predicted on a digital mechanization, that is, ones and zeroes, so that considerable device degradation can be allowed without suffering sensor parameter variations. The analog display design is based on the use of high performance, tight tolerance components, whose drift directly affect sensor performance. Such devices also frequently require adjustments to accomodate statistical variation in component values.

SECTION IX

RECOMMENDATIONS

This section addresses recommendations for system modification, further development, tests and investigations. Texas Instruments Incorporated considers these to be invaluable to the development of future digital signal transfer unit and multisensor display systems.

A. System Modifications

1. Automatic Erase in Narrow Scan

This modification will result in automatic memory erase as the narrow radar sector scan is manually slewed across the antenna scan coverage. The modification requires changes to the memory timing control circuitry and will necessitate added circuitry.

2. Slow Raster Fly-in

The phosphor protection circuitry can be modified to use direct coupled sweep instead of capacitive coupled sweeps to speed up raster recovery in switching from radar to television modes.

B. Further Development

1. Symbol Recording

Symbol recording mechanizations were discussed in a previous section. No formal trade-off analysis has been performed to determine which approach yields the most optimum results for the F-4E application. The suggested development effort consists of a design analysis of the two approaches and specific identification of the implications of each to recording playback and system reliability.

2. Self Test Mode

Experience with the display/radar/TV interface in the aircraft has indicated that the radar bit tests do not adequately isolate problems between the sensors and the display. This, in turn, results in lost time in analysis of the problem source. Development of a simple DSTU self test mode could drastically reduce such excessive maintenance time.

C. Testing

1. Non Linear Analog-to-Digital Conversion

The AFAL flight tests showed that the inverse log quantizer greatly enhances DSTUMDS radar imagery. At this time, it is not known what non-linear quantizer response is optimum. Since the circuit response is easily changed, it is recommended that either a flight or bench test phase be initiated which will enable determination of this optimum response.

2. Electromagnetic Interference (EMI) Survey

Satisfactory performance was achieved by the DSTUMDS in the F-4E aircraft environment; no EMI problems were evident. However, very little is known about the system performance over the MIL-D-6181 spectrum. An EMI survey conducted on the DSTUMDS would provide valuable data in the identification of any potential trouble areas.

D. Investigations

A failure experiment during the flight with the mirrored CRT prevented obtaining useable data related to the device performance. Operator comments indicate that the concept does offer increased display contrast. It

is the opinion of Texas Instruments Incorporated that further investigation should be conducted to, not only verify that the device offers improvement, but also to determine what parameters of a CRT and filter combination achieve optimum performance.